The employment of knowledge visualisation to facilitate tacit knowledge sharing

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Abstract

This research explores how knowledge visualisation can support the sharing of tacit knowledge. One research question guides the study:

How can knowledge visualisation facilitate tacit knowledge sharing?

The research employed semi-structured interviews, non-participatory observations, and document reviews to collect data from 35 participants in 19 organisations and eight industries. Research data were analysed with thematic analysis, with the help of ATLAS.ti™ software. Moreover, in-depth case studies were conducted to verify data saturation.

The findings from this research show that the participants have little accurate understanding of the terminology being used in the academic literature to describe knowledge and tacit knowledge, and that participants in different industries use dissimilar definitions and knowledge sharing toolkits. It was found that tacit knowledge is shareable in the form of natural language expressed by stories, metaphors and cases, for instance, and by other representations such as visual. While it may not offer the complete solution, Knowledge visualisation can facilitate tacit knowledge building and sharing by providing the big picture, rapid scanning of detail, and rich connections.

It is concluded that knowledge visualisation is a powerful tool to support and to facilitate the sharing of tacit knowledge. Also, a new generation of knowledge represtations could usefully address extended questions on how tacit knowledge sharing can best be facilitated using knowledge visualisation.

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Glossary of Terms

In this thesis, the following abbreviations and terms appear frequently:

ABBR.	RELATED TERM	EXPLANATION
EK	Explicit knowledge	Explicit knowledge has an objective nature and can be expressed and shared in tangible form (Nonaka et al., 2000)
KM	Knowledge management	The management of supporting data and information, plus the management of particular expertise (Blair, 2002)
KR	Knowledge representation	A surrogate for abstract notions such as actions, processes, belief, causality, and categories (Davis, Shrobe, and Szolovits (1993). A substitute for the thing itself.
KV	Knowledge visualisation	All graphical means that can be used to construct, assess, measure, convey or apply knowledge (i.e. complex insights, experiences, methods, etc.) (Eppler & Burkhard, 2007, p. 112)
TK	Tacit knowledge	Tacit knowledge has a subjective nature and is highly personal and hard to formalise (Nonaka et al., 2000)

Chapter 1 : Introduction

This chapter introduces this thesis by addressing the background, challenges and motivation for conducting the research. An outline of the report is presented.

1.1 Research Background

Knowledge is a pillar of innovation and a critical source of organisational competitive advantage (Kabir & Carayannis, 2013). The ability to create and share it is regarded as a critical element for organisational success (Holsapple & Joshi, 2002). Here knowledge sharing is referring to the process of knowledge exchange (Lilleoere & Hansen, 2011) at the individual level or the distribution of existing knowledge within or across the organisational boundaries (Grant, 1996). However, managers and academics are paying attention to explicit knowledge (EK), or the conversion of tacit knowledge (TK) into EK (Nonaka & Takeuchi, 1995). There are several misunderstandings about knowledge and knowledge management, which attempt to put subjective knowledge into the objective or physical assets category. For example in the healthcare industry, knowledge management systems are employed to manage all knowledge, even TK, with the help of information communication technologies (Abidi, 2001).

To manage or explore the full potential of TK the available tools need to be re-examined. All knowledge is "either tacit or rooted in tacit knowledge" (Polanyi, 1969, p. 195). In other words, knowledge is closely related to its owners and users—the individuals who are the fundamental repositories of TK (Gubbins et al., 2012). TK is always intangible, hard to express but also valuable to individuals or organisations. No matter how a person acts, that action is on the basis of their TK (Engel, 2008). To get access to and utilise TK, appropriate tools such as externalisation and internalisation (Nonaka & Takeuchi, 1995), or codification (Schulz & Jobe, 2001), are employed. Nevertheless, the externalisation of TK may be difficult or even impossible (Hislop, 2013; Tsoukas, 2003).

Visuals would appear to be a promising tool to help extract more potential from TK sharing. Boland Jr. et al. (2001) suggest that portraying abstract knowledge in figurative, as well as literal forms, is possible to enhance the knowledge transfer

process. This view provided an early pointer for this research. As Flusser (2002) contended, language is linear and one-dimensional, while visuals include a two-dimensional surface or three-dimensional spaces which might bring the potential for TK sharing. Styhre and Gluch (2009) posited that visual representations deserve a more detailed analysis.

Hence, this study aims to explore practical approaches of TK sharing in the business environment with the help of visuals.

1.2 Challenges to Tacit Knowledge Sharing using Visuals

In practice, there are two main challenges for individuals and organisations when they seek to share their knowledge with a visual.

The first challenge is related to the fact that **most of our knowledge is tacit and is difficult to express and share**. Knowledge is a vague and tricky concept about which academics have argued for many years, and many knowledge practitioners have no idea about what it is, even though they work with it every day. Although learning and storing knowledge seems automatic, the outgoing process of recalling our knowledge, utilising it, and putting it into other representations, seems difficult and requires higher levels of expertise plus appropriate tools (Brockmann, 2011). These considerations make knowledge sharing difficult. Furthermore, multiple approaches are proposed: such as a Community of Practice (Lave & Wenger, 1991), SECI (Nonaka & Takeuchi, 1995) and practical immersion (Muñoz, Mosey, & Binks, 2015). A case study of TK sharing in the Australian film industry, by Alony, Whymark, and Jones (2007), demonstrated the significance of knowledge sharing to organisational performance. However, there appear to be little empirical cases in the business setting for TK sharing.

The second challenge of knowledge sharing using visuals, especially TK sharing, is the need to consider the perspective of the sender and the receiver. TK is hard to express, so is it even possible to express via a visual? Can a visual facilitate knowledge sharing? Is it an efficient and effective process? The wide variety of available visualisations, including tree diagrams (Massironi, 2002), visual categorisations (Mayer, 2009), the seven communicative visualisations (Clark & Lyons, 2010), visual vocabularies (Horn, 1998, 2001), the knowledge visualisation (KV) framework (Eppler & Burkhard, 2007), and the periodic table of visualisation

methods (Lengler & Eppler, 2007), make it very difficult to obtain a clear picture of the visualisation taxonomy, and equally difficult for practitioners to choose the appropriate tool(s) from the toolbox. Research in this domain must balance between the complexity of applications in the real world and the detail needing to be explored as an academic endeavour.

1.3 Research Motivation

The two research challenges outlined above are important for understanding the knowledge sharing processes in real organisations. Four main reasons motivated the researcher to conduct this research:

First, much confusion in the literature plus the specific practical, real-world needs of knowledge management (KM) motivated the researcher to explore the field of knowledge sharing. People do not appear to have a clear idea about what knowledge is all about despite using it every moment to learn, and to practise and apply their skills. Regarding the issues of knowledge hoarding (Ardichvili, 2008; Jones & Leonard, 2009) and knowledge sharing, a synthesis of people's perceptions of knowledge and related terms is needed for better understanding and better deployment of knowledge sharing tools.

Second, since knowledge can only be acquired and shared by individuals, knowledge sharing becomes an interpersonal phenomenon (Leppälä, 2012), with the holders/senders on one 'side' and the receivers on the other. The result of knowledge sharing is that knowledge is held jointly by both the original knower (the one who practices and uses knowledge) and the receiver (who are also knowers) (Johnson, 2007). *While not completely neglecting the receivers, this thesis focuses more on the holders/senders, because a successful sharing process requires the holders/senders to 'stand in the shoes of the receivers'.*

Third, to achieve the research goal, this research explores the intersection of three domains: TK sharing, KV, and visual communication. Most research has been conducted within the individual domains. However, some researchers have paid attention to hybrids, such as visualising TK (Busch, Richards, & Dampney, 2001; Clausner & Fox, 2005), visualising expertise in the medical industry (Engel, 2008; Kinchin, Cabot, & Hay, 2008), visualising TK in education (Wang, Su, & Hsieh,

2011), and TK visualisation (Medeni, Medeni, & Tolun, 2011). Very little research has focused on TK visualisation in practical business contexts.

To help fill this gap, this research explores how KV can help share knowledge, including TK, in a business workplace context. It investigates the effectiveness and efficiency of KV and knowledge sharing for organisations. *Knowledge sharing in this thesis is taken to mean encoding the understanding of the knowers for communication with the receivers.*

Fourth, the researcher has a background in engineering and management. The topics of knowledge hoarding (Ardichvili, 2008; Jones & Leonard, 2009) and (time-consuming) mentorship have long puzzled the researcher. Could there be a better approach for facilitating TK sharing? The adage that 'a picture is worth a thousand words' motivated the author to understand the potential power of visualisation, especially with the visualisation tools available today that are being used to explore intangible and ambiguous problems.

This thesis advances the interpretation of how knowledge is shared and how it is processed with the help of graphics. The descriptions herein are built upon a critique of existing intellectual frameworks while also offering a conciliatory approach that suggests workable compromise.

This research can be of benefit not only to business practitioners but also to academic researchers. Practitioners will better understand the visual tools they employ to share their knowledge, especially their TK, by realising the mechanics and options KV can provide. Business people do not need to limit themselves to verbal communication, and will feel more comfortable when they know that effective and efficient KV is not difficult to achieve. Academic researchers will benefit from the empirical data to broaden the research domain, thus potentially opening further avenues for KV research.

1.4 Thesis Outline

The following chapters analyse and discuss the literature in areas related to KV and justify and illustrate how this research was conducted. The findings are presented, which are then compared and contrasted with the extant literature in a discussion

that leads onto the original contributions of this research and future research directions. This thesis presents as six chapters, Figure 1.1:

Chapter 1 addresses the background and motivation for this research, presents the main research challenges and the motivations, and emphasises the importance to organisations of TK sharing with the aid of KV tools.

Chapter 2 provides a detailed literature review that begins with basic definitions of knowledge, TK and TK sharing, and moves onto knowledge representations and visualisation. A summary is provided.

Chapter 3 describes the rigorous methodology that was used in this research. It outlines the considerations, justifies the choices that were made, and illustrates the correctness for answering the research question.

Chapter 4 reports the research findings within individual themes and showcases detailed data from the field work.

Chapter 5 compares selected findings with the extant literature in order to elicit and discuss a coherent story.

Chapter 6 presents the conclusions. Future directions are elaborated upon and the contributions to knowledge are highlighted. Promising future research directions are outlined and the main limitations of this study are presented.

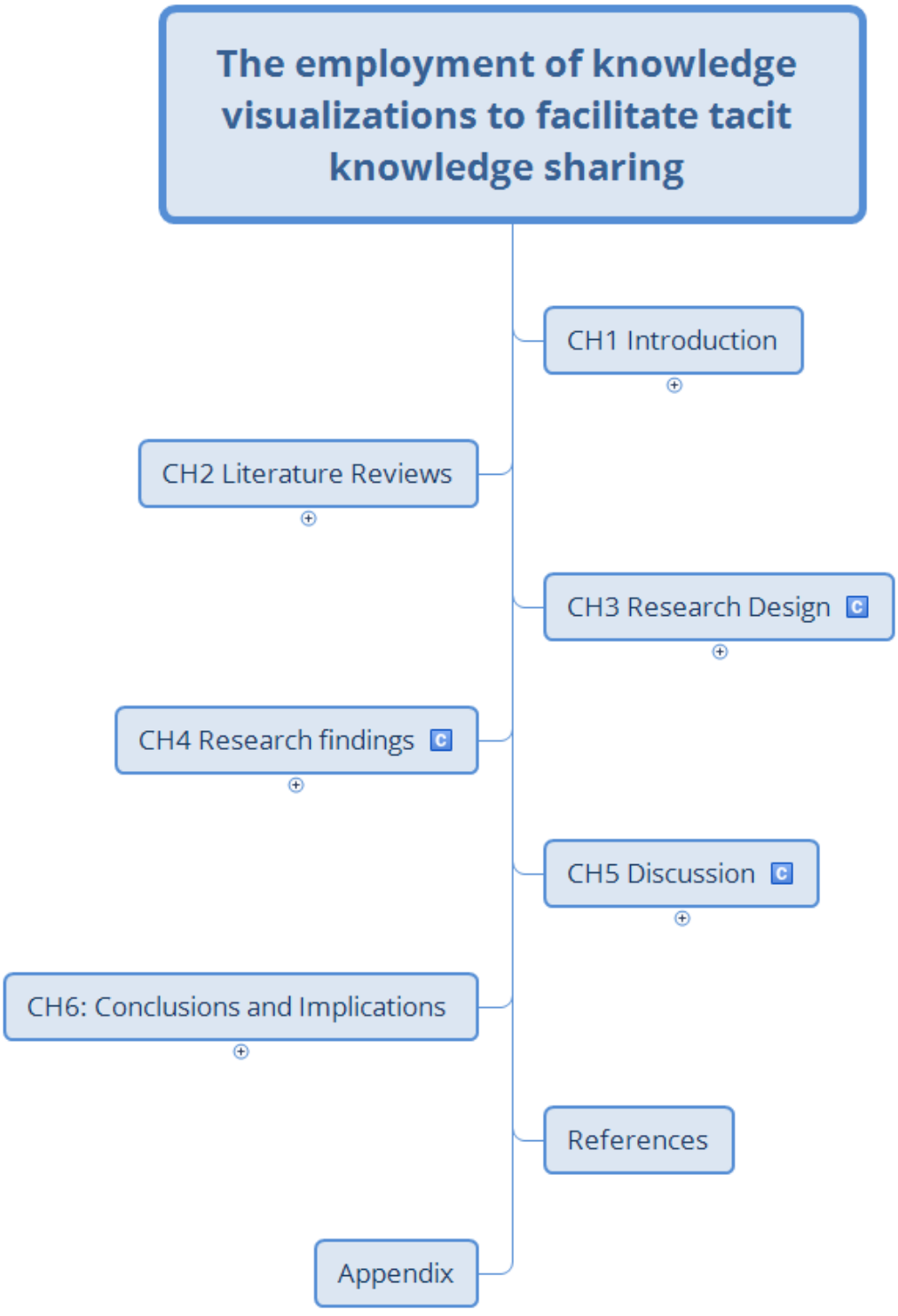

Figure 1.1: Structure of the report

Chapter 2 : Literature Review

2.1 Introduction

Knowledge is valuable and there are endless debates about its definition, exploitation (Liu, 2006) and visualisation. This section reviews the extant literature and justifies the basic concepts and applications of knowledge, and such related terms as TK, knowledge sharing and KV.

The review begins with the knowledge concept, TK and TK sharing, before moving onto KV, and shining a light onto knowledge sharing with visualisation. Several research gaps are offered in a summary at the end of the chapter, Figure 2.1.

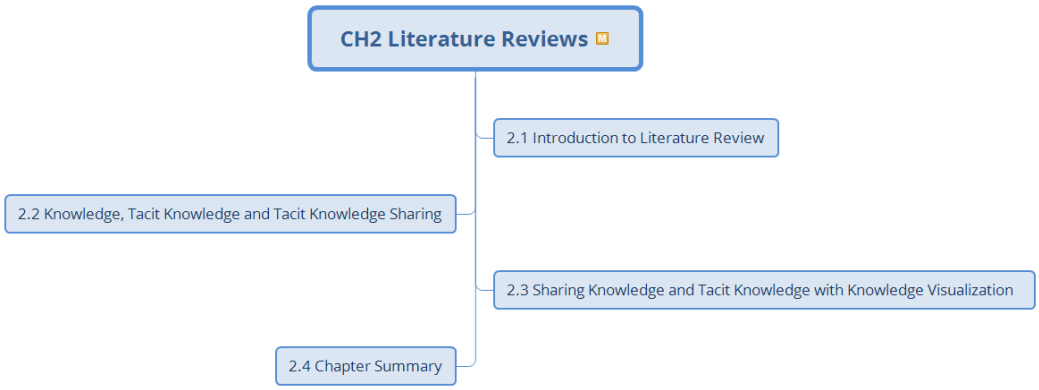

Figure 2.1: Structure of the Literature Review in Chapter 2

2.2 Knowledge, Tacit Knowledge, and Tacit Knowledge Sharing

This section begins with multiple views and debates of knowledge.

2.2.1 Multiple Views of Knowledge

The concept of knowledge is important but complex and controversial (Jakubik, 2007). Numerous variations of knowledge definitions are observed within different contexts (Kabir & Carayannis, 2013): knowledge in the world or knowledge in the head (Keller & Tergan, 2005), conceptual, episodic, procedural enactive, or situated knowledge (Rumelhart & Ortony, 1976).

Debates exist within three main streams observed from the academia: Justified True Beliefs (Gettier, 1963; Turri, 2012; Virtanen, 2010), Data-Information-Knowledge-Wisdom (DIKW) hierarchy (Ackoff, 1989; Alavi & Leidner, 2001; Blair, 2002), and a cognitive approach (Davenport & Prusak, 2000; Geisler, 2008; Gubbins et al., 2012; Minsky, 1986).

Some scholars from the Justified True Beliefs (**JTB**) school attempt to confirm that at least one additional condition must be met for knowledge (Gottschalk-Mazouz, 2013). Others, such as Sartwell (1991) and his followers, attempt to drop the justification condition. Nonaka and his co-authors accept this classical definition of JTB but emphasise justification rather than truthfulness to support their knowledge conversion (SECI) model (Nonaka, 1994; Nonaka & Konno, 1998; Nonaka & Takeuchi, 2007; Nonaka, Toyama, & Konno, 2000).

The second stream, Data-Information-Knowledge-Wisdom (**DIKW**) or the info-laden definition, describes the evolution of information to define knowledge. This school attempts to explain the difference between information and knowledge, and how information 'grows into' knowledge (Frické, 2009); it is largely unsuccessful (Perry, 2005) and its conclusions are problematic (Gottschalk-Mazouz, 2013). Debates within this stream deal with the question of whether knowledge evolves all the way from data to information to knowledge and then finally to wisdom, or in the reverse direction, from wisdom to knowledge to information to data, or whether the evolution is accumulated or linearly developed (Hey, 2004).

The third stream, **the cognitive approach**, relates knowledge with experience and mental models from a cognitive viewpoint. It suggests that the brain stores facts, then relates them to existing experiences to create one's own perception of the world (Gubbins et al., 2012). One's knowledge of a subject is then one's ability to answer questions about the subject. Geisler (2008) proposed the 'neuronal model', which declares that sensory elements are clustered by a knower in successive iterations, leading to the creation of knowledge. The elements of knowledge are conjoined to form meaningful representation of nature and the knower's reality, and are continuously added to the body of knowledge that exists in the knower's possession that can be shared by other knowers.

The confusion over a knowledge definition leads to confusion in choosing appropriate tools to take advantage of knowledge and TK. Keller and Tergan (2005) followed the DIKW approach when discussing how KV could be implemented. Coffey, Hoffman, and Cañas (2006) used knowledge modelling without defining what knowledge is. Hays (2010) employed Causal Loop Diagrams, referring to them as relationship or influence diagrams, to map wisdom. Hou and Pai (2009) claim to be dedicated to KV, while their objects of visualisation appear to be information. Moreover, the debates around knowledge mainly arise from academics rather than knowledge practitioners.

2.2.2 The Importance of Knowers

It is necessary to emphasise the importance of the knowers–those individuals who practice and use knowledge. Here, the term 'knower' is used as an umbrella term for knowledge holders *and* receivers. This is for several reasons:

Firstly, knowers are the cornerstone of this research. *This research begins with individual knowers to observe how they share their knowledge*. When the researcher deals with the application of knowledge, the first question is, Whose knowledge is it? Even organisational knowledge is commonly held by a group of people, hence it is necessary to identify the owners of knowledge or which group it comes from. The rules or routines all depend on the understanding and practice of the knowers.

Secondly, it is necessary to emphasise the importance of knowledge owners since it is believed that knowledge is individualistic. All knowledge is acquired by the knowers by means of physical and mental processes (Engel, 2008) and exists within the heads of individuals. Polanyi (1966) made this clear when he wrote that: "all knowing is personal knowing" (p. 4). Williams (2007) proposed that EK is simply information. In his eyes "a book of knowledge is really a book of information that contains indications of the knowledge of the author(ity) who wrote it" (Williams, 2007, p.125). It is difficult to isolate knowledge from its owners because, as Blair (2002) argued, "only a person can have and exercise knowledge" (p. 1021). Furthermore, the individually-held approach to knowledge is stressed by personal knowledge management (Jarche, 2013) and people-focused knowledge management (Wiig, 2004).

Thirdly, it is important to recognise the role of knowers in the organisational context. Attempts to define knowledge or organisational knowledge in objective terms tends to neglect the owners of knowledge. Many terms (knowledge codification, knowledge capture, knowledge conversion) all tend to neglect the owners but the knowers—the employees in the organisations—are very important because they possess something greater than the data and information stored in the organisation's information system. Also, organisations are looking after their employees rather than the outcomes of their employees (Blair, 2002). From this perspective, KM is mainly about managing people—the knowers of knowledge rather than managing knowledge itself (Johnson, 2007), which requires active management and support of expertise (Blair, 2002).

Fourthly, from the perspective of knowers it is much easier to identify the knowledge process at the individual, group, organisation and intra-organisational levels. Blair (2002) points out that managed knowledge is not easily separable from the knowers. Accordingly, the repositories of knowledge—the practitioners themselves—should be managed rather than the repositories of data and information. At the same time, knowers must be encouraged to pass their knowledge to others through personal contact. He concludes that KM includes not only the management of supporting data and information, but also the management of a specific expertise, which is found in individuals having specific abilities.

Finally, focusing on individual knowers helps this researcher to concentrate on the interaction between knowledge sharers and receivers. This research embraces a constructivism approach (Crotty, 1998) that treats knowledge as constructed by different people in divergent approaches. This choice is consistent with the research epistemology, which is discussed in the next chapter. However, this research avoids social constructivism (Burr, 2015; Weenink & Bridgman, 2017) and treats taken-for-granted knowledge as commonly-held prior knowledge held by individual knowers. This research emphasises on individuals rather than social interaction.

Thus the individual knowers are important and are the focus of this research.

2.2.3 Knowledge Building and Sharing

This section discusses the mechanisms involved in knowledge building and sharing. The enablers/barriers and purposes of knowledge sharing are also considered.

2.2.3.1 Mechanisms for Harvesting New Knowledge

Numerous researchers suggest that new knowledge comes from a combination of new information and prior knowledge (Gubbins et al., 2012; Reagans & McEvily, 2003). People learn by associating the incoming information with what they already know. This learning mechanism is explained by cognitive scientists via complementary bottom-up and top-down processes (Goldstein, 2010). The bottom-up process internalises the incoming information from the external reality to the brain, while the top-down process, the person's response, integrates the incoming information with the individual's prior knowledge. The new knowledge becomes the individual's prior knowledge and the processes starts over.

The connection between knowledge building and sharing has been extensively discussed in the literature (Chen, 2010; Chou, 2005; Lilleoere & Hansen, 2011; Reagans & McEvily, 2003) . Chou (2005) argued that three kinds of issues may affect knowledge building: the individual's ability to absorb and share knowledge, organisational learning mechanisms, and the ability to store and retrieve prior knowledge. Absorptive capability refers to the knower's ability to identify, assimilate and utilise prior knowledge (Chen, 2010; Reagans & McEvily, 2003). Lilleoere and Hansen (2011) note that the pharmaceutical industry has a fundamental need to acquire more innovative products for better sales performance. One implication of the learning mechanism is that, if emitters and receivers share common prior knowledge, it will be easier to share knowledge from the source to a recipient (Reagans & McEvily, 2003).

2.2.3.2 Knowledge Sharing

Knowledge sharing can be seen as a process of knowledge exchange (Lilleoere & Hansen, 2011) at the individual level or the distribution of existing knowledge within or across organisational boundaries (Grant, 1996). Knowledge sharing has a positive influence on organisational performance (Nonaka & Takeuchi, 1995). Knowledge sharing is a two-way process: from/to the knowledge source and to/from the knowledge receiver. For the first of these interactions, knowledge flows

from the knowledge emitter to the receiver, which is the main assumption for research in this domain. For the second interaction, a feedback loop transmits from the receiver to the source. Fang, Hari, Bruno, and Xiaoyun (2012) argue that if the sources pay attention to the feedback loop they can learn from the receivers. The loop assists shared understanding and thus facilitates the knowledge sharing process with the outcome of new knowledge for both parties. In this sense, knowledge sharing cannot ignore the possibility of the knowledge building process on either side; the source and the receiver.

In the literature, factors that promote knowledge sharing include a supportive culture (Ardichvili, 2008; Lilleoere & Hansen, 2011; O'Dell & Grayson, 1999), mutual trust and pay-off between colleagues (Ardichvili, 2008; Cabrera & Cabrera, 2002; Lilleoere & Hansen, 2011), and the availability of information services support (Ardichvili, 2008; O'Dell & Grayson, 1999). The main barriers (Lilleoere & Hansen, 2011) are a: lack of knowledge sources, lack of incentives to find knowledge, lack of support to reach knowledge sources, and hard to acquire knowledge (Ardichvili, 2008; Gupta & Govindarajan, 2000; Lilleoere & Hansen, 2011; O'Dell & Grayson, 1999).

2.2.4 Tacit knowledge

The explicit versus tacit dimension is concerned with how well knowledge is articulated or whether it is implicit (Bhagat, Kedia, Harveston, & Triandis, 2002)). The tacit dimension of knowledge was conceptualized by Polanyi (1966), who explained that TK consists of things "**we can know but we can't tell**" (p.4), an understanding that was later expanded by Nonaka (1994) to the organisational level.

2.4.1.1 Individual Tacit Knowing

Researchers believe that it was Polanyi who invented the term 'tacit knowledge' (Polanyi, 1959) when he was giving lectures at the University College of North Staffordshire in 1958. Tacit knowing encapsulates the concept that "we can know more than we can tell" (Polanyi, 1966, p. 4); we are the subjects—not the objects—of our own experience (Hall, 1979) .

Polanyi (1962) proposed three aspects of tacit knowing: the functional, the phenomenal and the semantic (Tsoukas, 2003, p. 7). The first, functional aspect of tacit knowing, refers to the vectorial character of human awareness, the subsidiary and often subliminal events without cognisance (Meek, 2017) which serve as TK seeds, which exist as such by bearing on the focus to which we are attending (Polanyi & Prosch, 1975) (see Figure 2.2). The second aspect involves the transformation of subsidiary experience, for example body movement, into a new sensory experience, while the final aspect is the meaning of subsidiaries, which is the focal target on which they bear. This process works like an upward spiral with the interiorisation of tools, such as a hammer for nailing. Based on TK seeds (subsidiary particulars), the tacit knowing vector points to the focal target in the individual's mind with the external help of the interiorisation of tools.

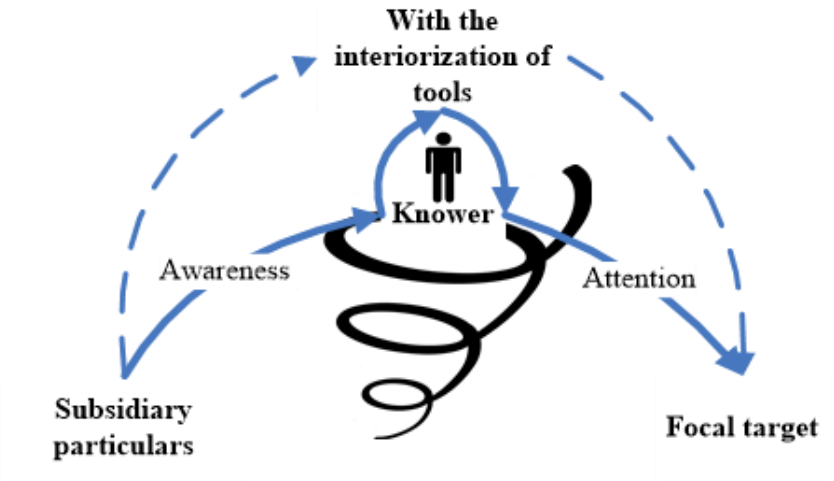

Figure 2.2: The Personal Knowledge Model

Source: Polanyi & Prosch (1975)

The word 'knowledge', whether or not it is used in terms of TK or EK, readily misleads one into thinking of a static condition, as if knowledge were a physical asset. However, Sternberg et al. (2000) suggest that TK is a subset of procedural knowledge (know-how), which guides people's behaviours in performing tasks in a given situation. This suggests a single dynamic upward spiral: the seeds of TK grow into new TK by people's involvement, and new TK yields new seeds as the new cycle begins (see Figure 2.2). Polanyi (1969) referred to this process of circular spiral progression as the dynamics of tacit knowing, "the questing imagination vaguely anticipating experiences not yet grounded in subsidiary particulars which

evokes these subsidiaries and thus implements the experience the imagination has sought to achieve" (1969, pp. 199-200).

The upward spiral can also be appropriate in either the individual or the organisational context. Polanyi focuses frequently on the individual aspect in his works (Polanyi, 1962, 1966, 1969; Polanyi & Prosch, 1975). In the organisational context, researchers show that a more knowledge-intensive environment tends to beget more investment in knowledge development, and organisations may find themselves in self-reinforcing spirals of knowledge-creating activity that cause high levels of organisational renewal and growth (Levinthal & March, 1993). This upward spiral was regarded by Cook and Brown (1999) as the "generative dance between knowledge and knowing" (p. 381) and they believe it to be the source of organisational innovation and new knowledge.

2.4.1.2 Organisational Knowledge Conversion

Nonaka (1994) affirmed that EK can be articulated in words and numbers, and can be shared in the form of data, scientific formulae and specifications. This kind of knowledge can be codified and transferred easily. In contrast, TK is difficult to communicate and articulate. It is highly personal and hard to formalise so it is difficult to share with others. TK includes cognitive and technical elements, (see Figure 2.3). The former centres on a mental model in which human beings create working models of the world by making and manipulating analogies in their mind. These include concrete know-how, crafts, and skills (Nonaka & Takeuchi, 1995) that guide people's behaviour to perform tasks in a given situation (Sternberg et al., 2000). TK is deeply rooted in the individuals' cognitive processes or ingrained in the routine and non-routine processes of an organisation's unique culture and values (Daft & Lengel, 1986).

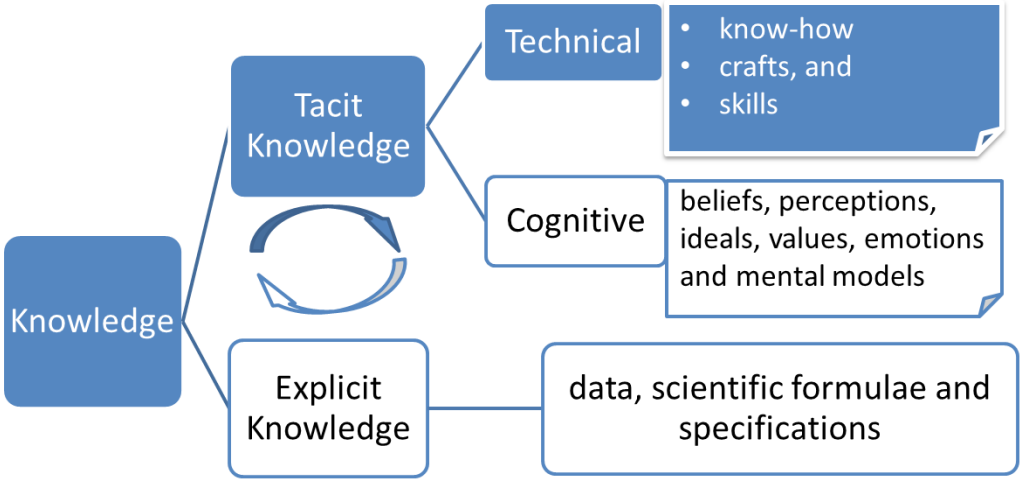

Figure 2.3: Knowledge and its Subcategories

Source: Nonaka and Takeuchi (1995)

The idea of the externalisation and sharing of TK became popular in the organisational context after Nonaka and Takeuchi (1995) had published their work. These authors understood knowledge in the traditional sense, as justified true belief, but they also highlighted the nature of knowledge as justified belief over its truthfulness; thought to be the focus of traditional Western epistemology. Based on this, their Socialisation-Externalisation-Combination-Internalisation (SECI) model illustrates conversion between tacit and explicit knowledge by four basic patterns: Socialization (from tacit to tacit), Externalisation (from tacit to explicit), Combination (from explicit to explicit), and Internalisation (from explicit to tacit) (Nonaka & Takeuchi, 1995). The most abstract point of this model is the externalization pattern—from TK to EK (Virtanen, 2010).

One issue needing to be addressed when moving from the individual to the organisational level is the paradigm shift (Mohamed, 2007). If knowledge is taken to be rooted in individuals, organisational knowledge should be the combination of individual knowledge, where knowledge is held as the common knowledge and shared by every member rather than being objective and documented in the explicit form. This shift in the paradigm of knowledge argues that we should not attempt to convert more TK into explicit form, but should "strengthen the transferability of that portion of knowledge that individuals are indeed capable of sharing and

diffusing" (Geisler, 2008, p. XIV). *This research focuses on the individual level of knowledge sharing.*

2.4.1.3 Accessing Tacit Knowledge.

It is commonly accepted that TK is hard to articulate but the question is, is it still accessible? An attempt, conducted by Busch et al. (2001) to map TK by linking concepts together, failed, as their object is really EK. If TK can be articulated, ipso facto it will become EK rather than TK. Balconi (2002) illustrated the point with the example of skilled workers who measure the temperature of steel from its colour, or workers who measure the uniformity of doping on silicon slices, from the distance of smoke rings in the doping furnaces. This shows that TK can be accessible if appropriate representations can be made to relate back to the TK.

Two camps of authors hold different viewpoints around the question whether TK can be articulated. One camp insists that TK and EK are two ends of a continuum, and the tacitness degree can be divided into several forms: deeply integrated TK that is accessible to the knowers; tacit skills that can be imperfectly articulated through the use of metaphors and storytelling; tacit skills that can be articulated through well-aimed probing questions; and at the other end of the continuum, explicit skills that can be easily communicated (Ambrosini & Bowman, 2001; Eraut, 2000). This view implies that TK will be articulable if we just use the 'right' methods, for example Nonaka and Takeuchi's (1995) popular SECI model.

The other camp claims that TK and EK are two sides of the same coin. Premised on Polanyi's (1962, 1966) philosophy, this camp asserts that even the most explicit kind of knowledge is underpinned by TK (Cook & Brown, 1999; Hildreth & Kimble, 2002; Ribeiro & Collins, 2007; Tsoukas, 2003). Thus, TK cannot be transferred or converted into explicit form, but "only displayed and manifested, in what we do" (Tsoukas, 2003, p. 1).

Although these two camps cannot easily be combined, what can be drawn from this discussion is that TK is accessible. Brockmann (2011) proposed a pragmatic approach by suggesting several techniques to access diverse levels of knowledge (see Figure 2.4**Error! Reference source not found.**). The concentric circles (spheres are better but are harder to visualise) show the various levels and types of knowledge: subconscious, tacit, preconscious and active conscious knowledge from

the heart to the surface. The arrows illustrate the different avenues to access TK: intuition, incubation, meditation, self-reflection, introspection, mental imagery, and metaphors/analogies.

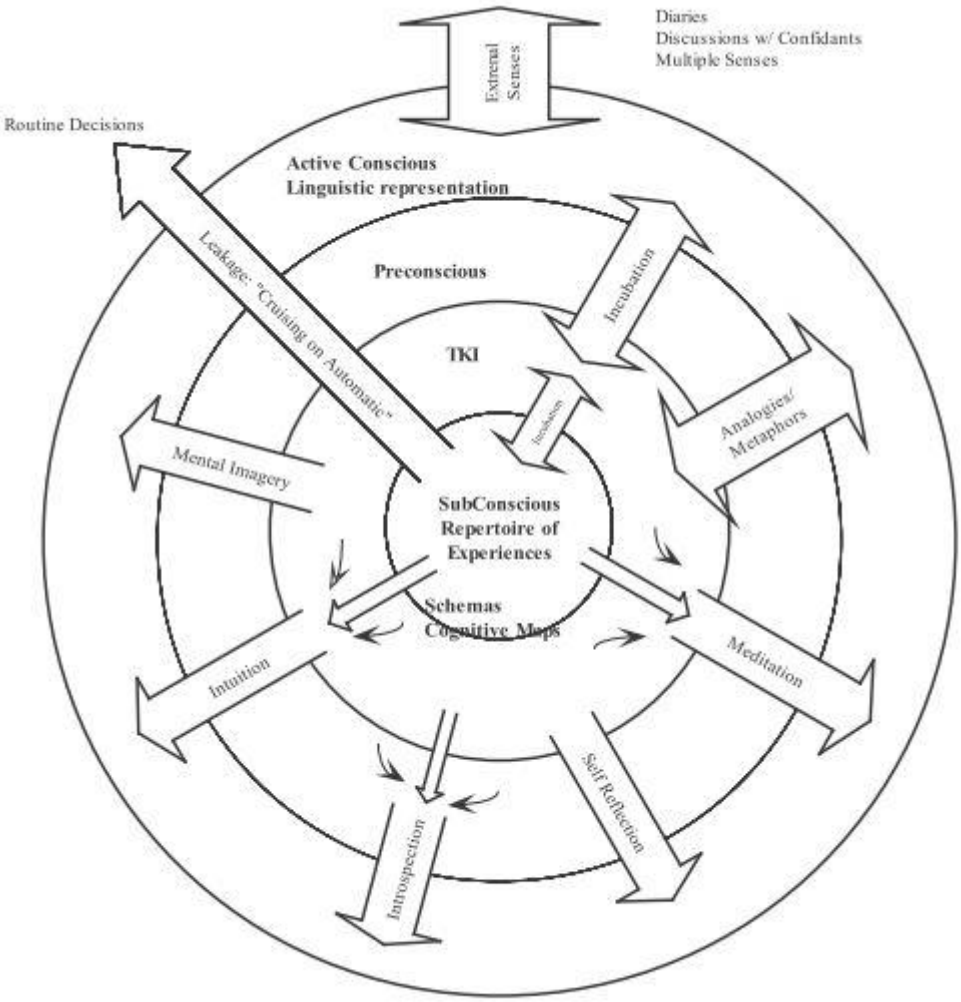

Figure 2.4: Levels of knowledge and avenues of access to them.
Source: Brockmann (2011)

Most of the avenues of access are meaningful for this research. Metaphors can be made into visuals, ‘visual metaphors’, being for example a bridge to link distinct parts of ideas together. Meditation and intuition, if used properly, can also yield potential from the deeper subconsciousness. Self-reflection and mental imagery are the approaches which can take advantage of TK. Introspection, the examination or observation of one's own mental and emotional processes, has different depths of communication between the conscious levels. Incubation can also work at distinct

levels of consciousness. Leakage from experience benefits from preconscious knowledge in a way that is similar to a 'gut-feeling' (Brockmann, 2011).

Nonaka and Takeuchi (1995) derived an epistemological dimension of tacit-explicit knowledge with an ontological dimension of knowledge levels (individual/group/organisational/inter-organisational). They took Polanyi's work on personal knowledge and extended it into a new field of cooperate or organisational knowledge (Grant, 2007). This research adopts the idea of the epistemological and ontological dimensions of knowledge, and attempts to observe how TK works for individuals in organisations.

2.2.5 Tacit Knowledge Sharing

2.2.5.1 The Importance of Sharing

TK sharing among team members can improve team performance (Refaiy & Labib, 2009), and successful knowledge sharing is shown to improve organisational performance (Alony et al., 2007; Ambrosini & Bowman, 2008; Fetterhoff, Nila, & McNamee, 2011). Sharing TK is thought to be a critical step for organisational knowledge building to take place among multiple individuals with different backgrounds, perspectives and motivations (Nonaka & Takeuchi, 1995). Four reasons for sharing knowledge in organisations can be illustrated with four metaphors (Scarbrough, 2003): the web (knowledge sharing as a means of establishing connections with others in the organisation), the ladder (sharing knowledge in the pursuit of status and career advancement), the torch (sharing knowledge after examples of leaders), and the fortress (sharing knowledge as a source of protection against external threats).

Many gaps currently exist in the literature, including whether it is important to share TK. Another concerns the argument over whether TK is articulable or not. Researchers (Ambrosini & Bowman, 2001; Eraut, 2000) believe that TK is not accessible although if proper methods are undertaken some TK can be articulable. As mentioned above, Cowan, David, and Foray (2000) argue that TK should remain uncodified, not because it is impossible but because the cost of codification exceeds the benefits (Leppälä, 2012). Tsoukas (2003) strongly argues that TK cannot be transferred or converted into explicit formm rather it is displayed and manifested in our actions. Another gap concerns the tools and techniques suitable for TK sharing.

Some researchers propose that TK can only be shared via the convention of EK (Nonaka & Takeuchi, 1995), while others argue for several techniques, such as intuition, incubation, mediation and mental imagery (Brockmann, 2011). Other researchers propose general techniques such as wikis, town hall meetings, mentoring, and reward programs (Mayfield, 2010).

2.2.5.2 Approaches to Sharing Tacit Knowledge

Regarding how TK can be shared, most researchers (Alony et al., 2007; Baker & Webb, 2011; Hou & Pai, 2009; Nonaka & Takeuchi, 2007; Orr, 1990; Tsoukas, 2003) agree that TK is sharable: from tacit to tacit, and from explicit to tacit. Of these two approaches, sharing TK in explicit forms tends to attract most attention from academics and practitioners. Supporters of this approach attempt to codify or document TK (Schulz & Jobe, 2001) as they hold the view that TK can only be shared when it is made explicit. The other view is that knowledge can be shared within tacit form. Nonaka and Takeuchi (2007) argued that valuable tacit skills can be acquired in multiple ways, for example via mentorship.

The literature reports that the TK once shared is not a copy of the original (Alony et al., 2007; Gubbins et al., 2012; Liu, 2014) . After sharing, the owners still have the knowledge while the receivers have a copy which may be different from the original knowledge, depending on the ability of senders and receivers. To achieve consistency, knowledge must be recreated in the mind of the receiver(s). TK sharing is bound with individuals and can only happen between people.

TK sharing can also happen at various levels: between individuals, from an individual to a group, between groups, and from individuals and groups to the entire organisation. Two dimensions can be borrowed from Nonaka and Takeuchi (1995) as the basic framework for knowledge sharing: epistemological and ontological. The epistemological dimension was discussed earlier. For the ontological dimension, TK sharing will happen in the individual, group, organisation or inter-organisation context. It should be noted that knowledge is only held in individuals and an organisation cannot create or share knowledge without individuals. Organisational TK sharing therefore should be understood as a process that organisationally amplifies the TK created by individuals and which has been crystallised as a part of knowledge seeds for others within the organisation.

2.2.5.3 Factors Affecting Tacit Knowledge Sharing

The extant literature revealed several factors that facilitate or hinder TK sharing. In a study of the film industry network, Alony et al. (2007) found six individual factors: the position of individuals in the network, network properties, properties of the knowledge shared, relationships and ties, organisational properties, and the level of trust. There are inter-relationships between these factors: for example, common knowledge has a positive effect on knowledge sharing, while diversity contributes to knowledge sharing effectiveness; strong ties encourage better tacit knowledge sharing; cohesion promotes better trust and enables knowledge sharing. Majewska and Szulczynska (2014) stress that trust is a critical factor and propose a higher level of application methods and practices for TK sharing. Knowledge tacitness, knowledge gaps, cultural and communication difficulties and weak relationships are identified by Chen, Sun, and McQueen (2010) as the critical factors for TK sharing in a cross-cultural context.

Barriers to TK sharing include perception, language, time, value, and distance (Mahroeian & Forozia, 2012). Perception or maturation of knowledge (Cumberland & Githens, 2012) barrier reflects people's awareness of their knowledge and their way to gain access to knowledge. Language barrier reveals the critical parts of TK sharing as TK is always held in non-verbal form and therefore creates a communication barrier (Cumberland & Githens, 2012). Time is considered necessary to develop tacitness of people's knowledge, but time-consuming activities hinder TK sharing. Value, which is embedded in culture, may become a barrier given today's diversity within organisations. Intervening distance makes conveniency (Cardinal & Hatfield, 2000; Napier & Ferris, 1993) a challenging factor for face-to-face interaction and TK sharing.

No prior research was found that examines the factors that affect TK sharing using visual representations.

To summarise, this section has examined the literature on knowledge, TK and TK sharing. The research gaps identified in this section are:

- The definition of knowledge in the literature is confusing, resulting in many choices among theories and tools. The question may be asked whether

people in the business setting face similar situations? Empirical work is lacking on perceptions in the field.

- Several enablers/barriers have been identified and tested in the literature. However, seldom is there a mention of knowledge representation. Is it possible to improve knowledge sharing through better use of knowledge representation?
- Some researchers insist that TK can only be shared by converting it into explicit knowledge, while others argue that new tools need to be employed. Empirical evidence is needed to resolve this issue.
- Multiple approaches have been proposed to gain access to TK, yet very little is known regarding how business people gain access to TK and share TK.

2.3 Knowledge Representation and Visualisation

KV as a field that combines KM with visualisation has become popular in recent years. This section will examine knowledge representations, categories of KV, the reasons for employing KV, its implications and its integration with TK, and finally the approaches for evaluating KV. Research gaps are summarised at the end of the section.

2.3.1 Knowledge Representation

This section will examine the theories of representations first, then consider knowledge representations with an emphasis on the literal-figurative dimension. It will finally highlight the abstraction-complexity dimension of representations.

2.3.1.1 Knowledge Representation Perspectives

Knowledge representation can be examined from the surrogate, commitment, and medium perspectives. Davis et al. (1993) propose that a knowledge representation is most fundamentally a surrogate, a substitute for the thing itself, which is used to enable an entity to determine consequences by thinking rather than acting. As surrogates for abstract notions such as actions, processes, beliefs, causality, and categories, representations allow them to be described inside. But since all representations are imperfect, which can be a source of error, selecting a good representation is "finding one that minimizes (or perhaps even eliminates) error for

the specific task at hand" (p. 19). Knowledge representations are also a set of ontological commitments to answer the questions people may encounter. Intelligent reasoning is expressed between the representation's fundamental conception and its inferences. Knowledge representation is a medium for organising information and facilitates expression. Knowledge representations are also a fragmentary theory of intelligence reasoning, a medium for pragmatically efficient computation, and a medium of human expression and communication to tell machines or human beings about the world.

Davis et al. (1993) recognised that it would be difficult to synthesise the various roles of surrogate, commitment, and medium, although some researchers did try to combine them. Keller and Tergan (2005) accepted the information-evolved approach, but also proposed two kinds of knowledge: knowledge in the world and knowledge in the head. These two kinds of knowledge correspond to the surrogate and medium roles of knowledge (Davis et al., 1993).

Accordingly, the academic exploration of knowledge representation is based on three foundations: mental models, channels, and receiver capacity. First, the importance of **mental models** (Minsky, 1986; Senge, 2006), or schemata (Boland Jr. et al., 2001) or cognitive maps (Gubbins et al., 2012) from which the representations draw upon, should be recognised. Mental models refer to deeply held internal images of how the world runs (Senge, 2006) and if they exist in shared or collective form, they can be considered to be collective TK (Chen, 2010), that is, the invisible, unspoken, unwritten knowledge found in organisations. Second, the **channel** encodes the knowledge representations into a literal or figurative abstract or concrete form (Boland Jr. et al., 2001). These authors suggest that portraying abstract knowledge in figurative as well as literal forms was possible to enhance the knowledge transfer process, which pointed the way for this research. Finally, the **capacity of the receiver** should also be considered from the viewpoint of the senders. An appropriate representation for specific receivers needs to be chosen to make the process both efficient and successful.

Different kinds of knowledge, whether explicit-tacit or declarative-procedural-conceptual knowledge, have different representations. Shute and Torreano (2002) propose that a semantic network can be used for declarative knowledge (knowing what), a production system which consists of actions and corresponding conditions

can be employed for procedural knowledge (knowing how), while mental models and a partially semantic network can represent conceptual knowledge (knowing why).

2.3.1.2 Literal-Figurative Dimensions of Knowledge Representation

Language, whether in written or verbal form, can be said to be the principal carrier or instance of knowledge (Styhre & Gluch, 2009). EK can be expressed in natural language so many researchers have taken advantage of this convenience, applying it to knowledge codification (Cohendet & Steinmueller, 2000; Cowan et al., 2000; Kimble, 2013a, 2013b), knowledge capture (Dean, Fahsing, Glomseth, & Gottschalk, 2008; Leake et al., 2003), knowledge conversion (Shute & Torreano, 2002), and knowledge transfer (O'Dell & Grayson, 1999; Reagans & McEvily, 2003).

The conditions needed for successful transfer of EK are often overlooked (Leppälä, 2012). It can be observed that experts can often identify and communicate more than laymen. Leppälä (2012) argues that the reason that some knowledge remains vague can be attributed to a lack of incentives, such as occur in a trusted institutional environment, rather than to tacitness. Even with full willingness the most eminent experts are doubtful of being able to share their un-articulable TK. Experts can apparently easily exploit their lower levels of knowledge, however for someone else the same knowledge may be at their higher levels so that they struggle to extract full potential from their knowledge bank.

Although transforming knowledge into explicit form with the help of natural language is a current topic, the disadvantages of language bring inconvenience in terms of sharing knowledge. Firstly, modern languages use levels of abstraction by repeated modularisations in a hierarchical way (van Leeuwen, 2014); readers need to spend time while following the same set of language arrangements. For example, regarding the encoding side of knowledge sharing, consider that a book that contains the knowledge of the authors might need to be thick and heavy to include enough useful knowledge. On the decoding side of knowledge sharing, readers would need to devote sufficient time and effort to reading the book and must subject themselves to a text analysis process and a reconstruction of the meanings.

Secondly, some parts of language cannot be neglected in term of communicating the inexpressible via metaphors or analogies. Can we say that what is transmitted via metaphors or analogies is explicit to the receivers? Metaphor or analogy is one of the avenues that was proposed by Brockmann (2011) to access TK.

Thirdly, as one of the representations of our thoughts, language can only exist at the active conscious level, it is energy intensive and therefore easily overloaded (Rock & Schwartz, 2007). However, most knowledge resides beneath this level.

Visual representations were introduced to help communicate the tacit aspect of knowledge. Näykki and Järvelä (2008) declare that visual representations as cognitive tools improve the understanding of students' learning process, and help students' self-regulated learning by externalizing their own thoughts as well as the thoughts of others.

Although this research focuses mainly on the visual part of knowledge representations such as drawings, sketches, and images, the literal part of knowledge representation cannot be totally neglected. Rather it needs to be integrated as a complementary tool to help the knowledge transmission process.

2.3.1.3 Abstraction-Complexity

Abstraction can help communicate information by allowing the encoders to select what would be highlighted or weakened (Berger, Shamir, Mahler, Carter, & Hodgins, 2013; Nan et al., 2011). Budd (1991) noted that an atlas will show "only the most noteworthy features" (p. 25), omitting smaller features. Calling the former "abstraction", and the latter "information hiding", he gave the following definitions for these two terms: "Abstraction is the purposeful suppression, or hiding, of some details of a process or artefact, to bring out more clearly other aspects, details, or structure" (p. 25). This definition of information hiding is echoed by van Leeuwen (2014) as "the purposeful omission of details in the development of an abstract representation" (p. 26).

Abstraction is an efficient strategy to cope with complexity. Boland Jr. et al. (2001) asserted that "knowledge is presented at a level of abstraction that transcends context to provide potential guidance in a wide range of situations" (p. 409). Abstraction introduces a higher level of concepts which is notably helpful in the understanding of information and information processing and transformation (van

Leeuwen, 2014), and organises the details of a system to enable a focus on the important elements of the big picture. Abstraction is the heart of thought (James, 1975).

Different levels of abstraction should accommodate different viewing strategies (Massironi, 2002; Wickens, Lee, Liu, & Gordon-Becker, 2003). Scaife and Rogers (1996) point out that the abstraction of material should meet "the varying demands of the task and learner's ability" (p. 207). Abstraction has its darker side, when a sacrifice of detail is chosen to gain a complexity and development-productivity advantage, which thus loses the ability to control those details (van Leeuwen, 2014). James (1975) warned that various abstractionist fallacies potentially lead to vicious abstractionism.

To sum up, as a vehicle for knowledge representation natural language plays a limited role in the sharing of knowledge, and more channels such as visual representations can be borrowed to enhance the process. *This thesis follows the constructionist approach of representation and examines the graphical side of knowledge representation with attention to the abstraction-complexity dimension.*

2.3.2 Categories of Knowledge Visualisation

This section explores the distinct categories and popular formats of KV, then compares specific forms and generating methods.

2.3.2.1 Categories and Criteria of Knowledge Visualisation

Various approaches are employed to categorise KV tools into different groupings. Lowrie and Diezmann (2009) classify graphics as context or information graphics with the emphasis on context graphics as representations of objects, people or location; while information graphics comprise the key points requiring decoding to accomplish the task. Clark and Lyons (2010) propose seven types of organisational graphic, focusing on purposes: decorative, representational, organisational, relational, transformational, and interpretive. Horn (1998, 2001) proposes that visual language can be examined from visual vocabularies with widely different types of visual formats. Eppler and Burkhard (2004) synthesise a KV framework which contains knowledge type (what), visualisation goal (why) and format (how). These categories tend to be either too general (Lowrie and Diezmann (2009) or are

otherwise weak in guiding KV users to choose the best too for the situation at hand. Two, more detailed categories were noted in the literature. One is the periodic table of visualisations from Lengler and Eppler (2007) that uses six basic groups to categorise 98 types of visual formats. The six groups are: data, information, concept, strategy, metaphor, and compound visualisation. Although the 98 types of visual formats cover most techniques that have been employed by people, the periodic table still offers only weak guidance for choosing KV tools since its six groups are vague in nature. Another category offered by Massironi (2002) is a representational/non-representational tree diagram consisting of 30 different types of graphic productions, Figure 2.5. It has two horizontal lines showing the extent/ level of being representational. The graphic productions are categorised as being representational (or not-representational) and also are linked to each other, indicating their relative levels of proximity. Graphic formats linked to the representational line are figurative while those linked to the non-representational line are abstract.

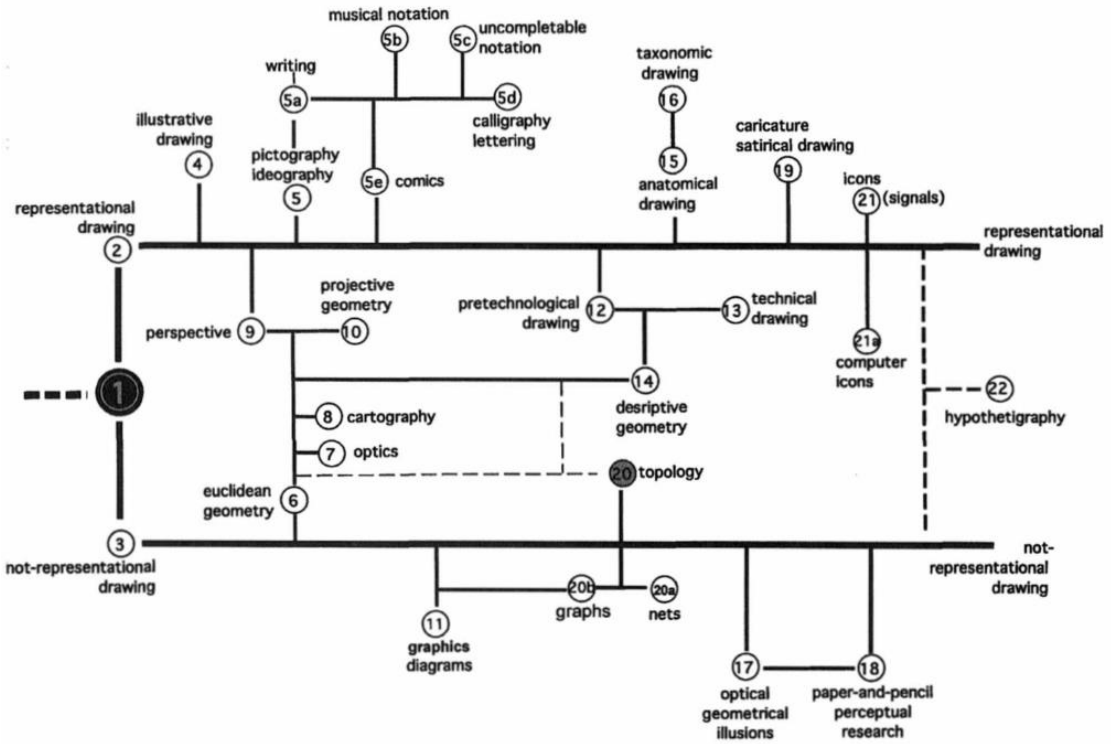

Figure 2.5: A Tree Diagram of Graphic Productions

Source: Massironi (2002, p. 3)

In terms of knowledge sharing, Massironi's (2002) approach provides a visual framework for sharing representational and abstract knowledge with a taxonomy of tools. As such it is helpful for this research. Firstly, it provides a simple structure having only two classes, which makes it easy for people to comprehend. Secondly, it provides a holistic map for all of the visual tools. For example, engineers and architects use pre-technological drawings, namely sketches, to illustrate a proposal for a problem or a design, and employ technical drawings later to help turn their proposals into physical artifacts. It is also clear that it might be possible to extend this approach. For example, the figurative/abstract dimension offers an approach to examine representations, while the other one can be used to investigate the domain of knowledge. If so, this would offer a useful framework for KV.

2.3.2.2 Popular Knowledge Visualisation Formats for Knowledge Sharing

KV focuses on structures of conceptual knowledge, with the most frequently used methods being mind-mapping and concept mapping (Keller & Tergan, 2005). Other methods, such as casual mapping, knowledge mapping, and knowledge metaphor, are also often used. Popular KV formats such as sketches, mind-mapping, concept mapping, casual mapping, visual metaphor and knowledge mapping are discussed next.

Sketches

Sketches are a powerful tool for sharing knowledge (Blackwell, Church, Plimmer, & Gray, 2008; Mitchell & Nørgaard, 2011; Pfister & Eppler, 2012). Pfister and Eppler (2012) define sketching as "hand-drawn, simple drawings on a poster, flipchart, piece of paper or via a digital pen on a tablet PC or an electronic interactive whiteboard" (p. 373). The use of such a visual language enables greater creativity and motivates participation in group discussions (Pfister & Eppler, 2012). The process of sketching has also been recognised as a conversation between the designer and the sketch (Schön, 1983) and it is clear that such visual abstractions have been used throughout history to communicate information (Berger et al., 2013).

Mind-mapping

In view of the differing right and left brain capacities, mind-maps are thought to be beneficial because they require active learning, they improve memory and learning

skills, encourage creative thinking and problem solving, and honour different learning styles (Peterson & Snyder, 1998). Researchers have also noted the "ripple effect" of metacognitive strategies yhat employ mind-mapping. Buzan and Buzan (1996) notes that:

> Mind-mapping reawakens (the) exceptional visualising capacity (of the brain). When the brain develops its ability to image, it develops its thinking capacity, its perceptual abilities, its memory, its creativity, and its confidence. (p. 74)

Mind-mapping, like other semiotic systems, can provide an array of choices of different ways objects and their relations may be represented (Worren, Moore, & Elliott, 2002). Figure 2.6 shows the combination of hierarchy, colour, images, line thickness and locus, and radiating branches utilised by the iMindMap™ software. This combination of characteristics makes mind-mapping a promising tool for communication. A central topic can be observed, which can reflect the focal target, and always keeps one's thoughts focusing on it.

Figure 2.6: Mind-mapping Example: Buzan's iMindMap

Source: http://www.techdigest.tv/2007/05/tony_buzan_laun.html

Branches radiating out from the centre show related ideas supporting the central topic and form a logic whole, and also give the users all the possibilities and the big picture. Those radiating lines can be formally called vectors (Kress & van Leeuwen, 1996) which translate similar meanings such as "action verbs" in language (example: "cause", "transmit", "send", "include") (Worren et al., 2002). Specifically, the action verbs can be shown with the different lines together, to strengthen the effectiveness of the visuals. Classifications show the distinct aspects

of thought on the central and sub-central ideas, implicitly indicating that standing at the same level means 'is equal' in some way. Visual metaphors or related images can be used to help the text express similar meanings, thereby strengthening the connection between the previous knowledge and the current information. Finally, putting all the elements together can establish memory cues and can "chunk" information into larger units to aid both encoding and retrieval (Glass & Holyoak, 1986).

Concept Mapping

Concept maps (see Figure 2.7) are defined by Novak and Cañas (2008) as ones that "include concepts, usually enclosed in circles or boxes, and relationships between concepts indicated by a connecting line linking two concepts" (p. 1).

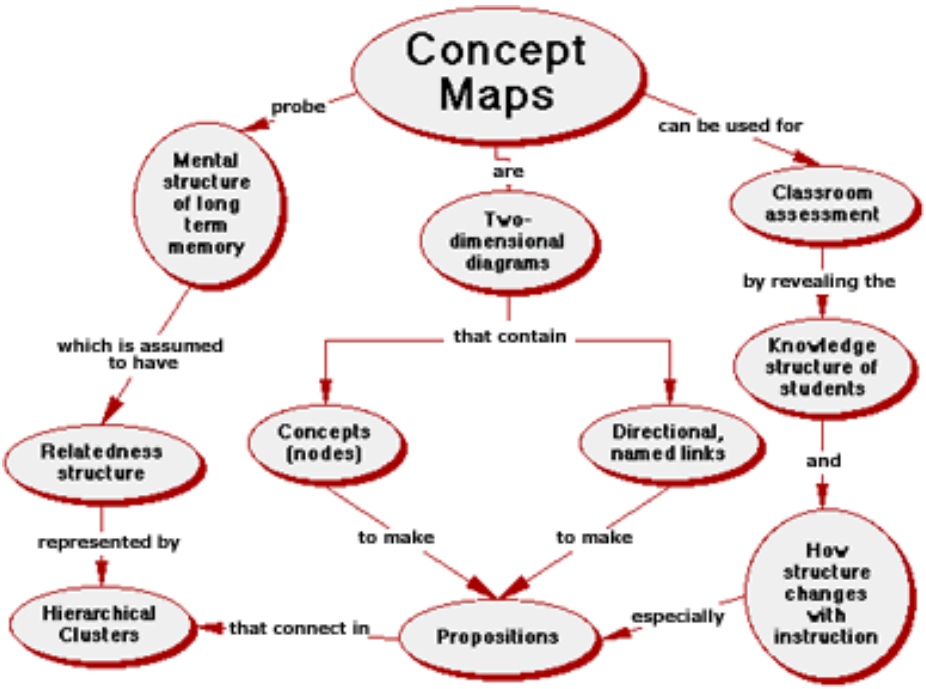

Figure 2.7: Example of Concept Map

Source: Michael Zeilik,

http://www.flaguide.org/extra/download/cat/conmap/conmap.pdf

In an educational context, a growing body of research indicates that the use of concept maps can facilitate learning. Concept maps have been shown to be of value as a knowledge acquisition tool during the construction of expert systems (Cañas, Hill, et al., 2004). Many researchers have paid attention to concept mapping tools,

including researchers at Cornell University; Indiana University; the Florida Institute for Human and Machine Cognition; and, the University of Waterloo (Buisine, Besacier, Najm, Aoussat, & Vernier, 2007; Cañas, Carvalho, et al., 2004; Cañas, Hill, et al., 2004; Derbentseva, Safayeni, & Cañas, 2004, 2006; Eskridge, Granados, & Cañas, 2006; Leake et al., 2003; Lee, 2004; Joseph D. Novak & Cañas, 2004; Joseph D. Novak & Cañas, 2006).

Hussain and Shamsuar (2013) attempted to use concept mapping to explore the field of knowledge sharing, and highlighted the need for further research into TK sharing. Shortcomings of concept mapping are discussed by Burkhard (2005b). Firstly, concept mapping can only represent propositional statements in which concepts are often described by verbal means alone, via textual labels. Secondly, traditional concept maps must be supplemented with 'know-where', with restrictions of know-what' and 'know-how'. This can be resolved with digital concept maps, which act as the main vehicle for easy access to information stored in a repository. Thirdly, concept mapping must consider the dynamic relationships between concepts, rather than staying with the predominance of hierarchical and static relations.

Causal Mapping

Causal mapping is a simple yet powerful technique that can help surface tacit skills (Ambrosini & Bowman, 2001). Ambrosini and Bowman (2001) used the causal mapping technique in their research on tacit skills (see Figure 2.8). The causal mapping technique, Self-Q technique (Bougon, 1983) and metaphors, are able to encourage participants to articulate their tacit knowledge.

1. Preliminary interviews about what causes success in the organization to elicit constructs to start the map (A, B and C)
2. Set up the map with the preliminary constructs as starting points
3. Begin the mapping process with questions such as:
   What causes that?
   How does it happen?
4. If the flow of constructs stops, ask questions such as:
   Could you give us an example of how that happened?
   Could you tell us a story?

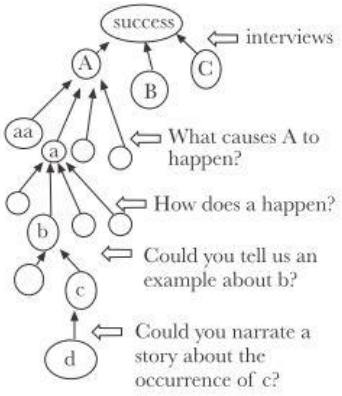

Figure 2.8: Example of Causal Mapping

Source: Ambrosini and Bowman (2001)

Visual Metaphors

KV using metaphors has proven to be a powerful tool. A metaphor can provide a way of moving from the understanding of something familiar to understanding something new, by carrying elements of understanding from the mastered subject into the new domain (Eppler & Burkhard, 2007). Worren et al. (2002) show how metaphors can also improve memorability and coordination in groups. Some researchers (Clausner, 2002; Clausner & Fox, 2005) have considered visual metaphors, and have introduced frameworks and toolkits for visualising TK. They focus on visual metaphors that represent temporal concepts about geospatial events and their qualitative uncertainties and basically use "visualisation as a means of conveying qualitative properties of tacit knowledge" (Clausner & Fox, 2005, p. 1). They accept that "the benefit of basing visualisation on metaphors is that they are a natural visual means of expressing tacit knowledge, just as linguistic metaphors are a natural means of expressing abstract concepts" (, p.2).

Knowledge workers use metaphors as a powerful way to utilise knowledge and communicate ideas. Researchers also use metaphors to explore the domain of knowledge. Hey (2004) was one of the first to undertake a metaphor analysis in KM theory, while Andriessen (2006, 2011) developed a more systematic approach by analysing the context.

Visual metaphor can be classified as natural objects or phenomena, e.g. mountains, icebergs, tornadoes, man-made objects, e.g. a bridge, a ladder, a temple, activities, e.g. climbing, and concepts, e.g. war, family (Eppler & Burkhard, 2007). Visual metaphor organises information meaningfully in dual forms; one illustrates information graphically by organising and structuring it, and the other can convey an implicit insight directly to the receiver(s) about the represented information through employing the key characteristics (or associations) of itself (Eppler & Burkhard, 2007). The documented ideas can be transferred again into personal knowledge for the receiver to attach what is new (the expert's insight) to what is already known (the previous knowledge, also the metaphor's main characteristic) (Eppler, 2003).

As indicated in Figure 2.9, visual metaphors organise information and give it additional meaning (Eppler, 2003) and also have a mnemonic function (i.e.,

facilitating remembering) and a cognitive coordination function (i.e., providing an area of mutual and explicit focus) (Eppler, 2003; Worren et al., 2002).

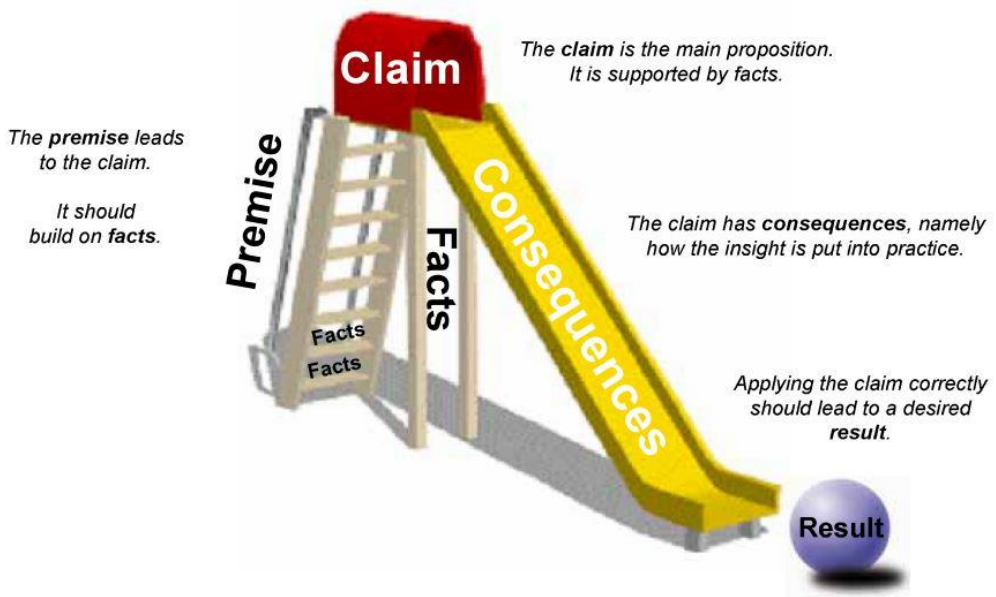

Figure 2.9: Argument Slide as a Reasoning and Communication Tool
Source: Eppler (2003)

Clausner and Fox (2005) focused on visual metaphors that represent temporal concepts about geospatial events and their qualitative uncertainties. They provided a TK framework and a toolkit for explicitly documenting the qualitative uncertainties and hypotheses that are implicit both in an analyst's data and their interpretation of that data. While they claimed to include TK in their framework (see Figure 2.10), this is not really TK but rather uncertain and distributed knowledge. Clausner and Fox (2005) also compared visual with linguistic metaphors: "The benefit of basing visualisations on metaphors is that they are a natural visual means of expressing tacit knowledge, just as linguistic metaphors are a natural means of expressing abstract concepts (p. 2)".

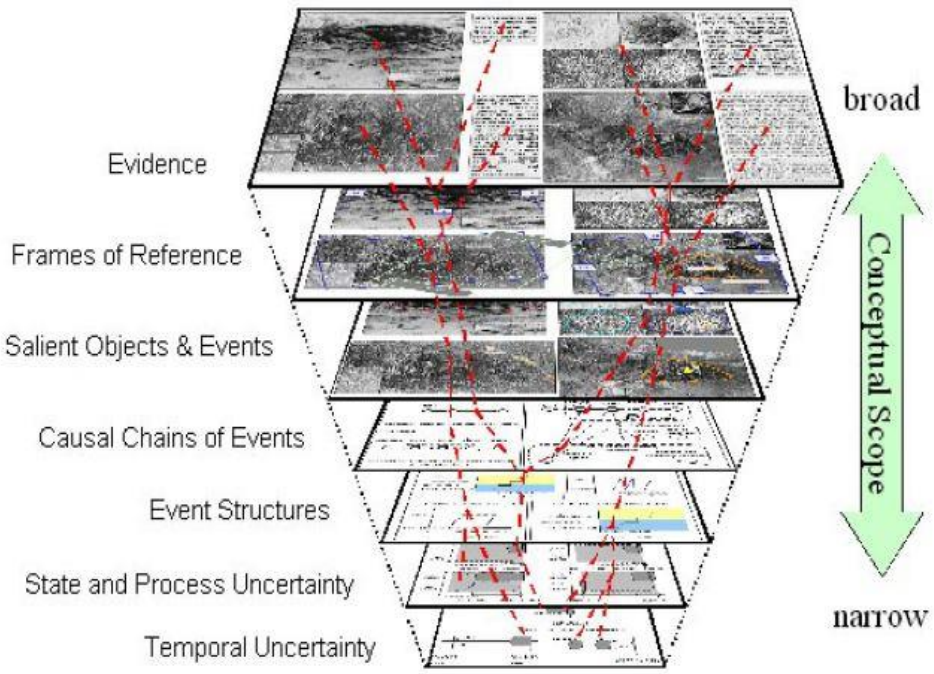

Figure 2.10: Tacit Knowledge Framework

Source: Clausner and Fox (2005)

Visual metaphors are not perfect, however. Although they can focus attention, compress knowledge, ease understanding, and motivate (interactive) participation (Eppler, 2003), they also have their disadvantages. It can be difficult to maintain diagrams and maps; invalid views can be brought into being, and manipulation of users and distortion of reality are possible through misinterpretations (Eppler, 2003).

Knowledge Mapping

Knowledge mapping embraces varied definitions. Eppler (2003) proposed a classification based on KM tasks: knowledge creation and development maps, knowledge identification maps, knowledge assessment maps, and knowledge application maps. The disadvantage of this model is that it is "not comprehensive, versatile, or precise enough to be of general use in knowledge management" (Eppler, 2008, p. 62). Eppler (2008) then synthesised knowledge mapping from researchers (Burnett, Illingworth, & Webster, 2004; Suresh & Egbu, 2004) as "a graphic overview and reference of knowledge-related content that serves a knowledge management-related purpose" (p. 62). After reviewing different classifications and classification principles, Eppler (2008) proposed a detailed knowledge map classification with criteria such as purposes, questions types and names.

While accepting their usefulness for communication purposes, Eppler (2008) admitted that knowledge maps may not be scalable or easily maintained, therefore needing trade-offs. O'Donnell, Dansereau, and Hall (2002) argue that knowledge maps are different from concept maps with three main categories of links used: dynamic, static and elaboration. They offered a useful literature review of using knowledge maps as scaffolds for cognitive processing. To sum up, a wide variety of KV exist in the literature, each with its own pros and cons.

2.3.3 The value of visualisation

The adage 'a picture is worth a thousand words' is the basic motivation why people favour using visuals, but looking inside the brain also provides some convincing arguments.

2.3.3.1 'A Picture is Worth a Thousand Words'

The well-known adage hints at the importance of using visuals to communicate, and reflects that a complex idea can be conveyed with just a single still image. It also aptly characterises one of the main goals of visualisation, namely making it possible to absorb substantial amounts of information quickly.

Although it is not clear how images are stored and recalled, humans have a natural ability to use them. Several empirical studies (Bauer & Johnson-Laird, 1993; Larkin & Simon, 1987; Novick, 2000) have found that visual representations are superior to verbal-sequential representations for various tasks. Visual representations can help users think about subjects in a global, holistic sense and increase mental flexibility (Mento, Martinelli, & Jones, 1999).

Empirical studies also show that **pictures can help people to comprehend and remember texts**. A learner may gain up to an 89 percent improvement in learning when a relevant visual is added to text (Clark & Mayer, 2011). Mayer and Gallini (1990) found that a diagram is 'worth *ten* thousand words' when the text is understandable, the value of illustrations is measured in terms of learner understanding, the illustrations explain, and the student lacks previous experience.

2.3.3.2 Inside the Brain: Visuals are the Productive Path to Knowledge

From a cognitive perspective, humans perceive visual scenes by imposing systematic organising principles (Koffka, 1935), and **knowledge is organised as if**

it were mental scaffolding that we impose on visual scenes in order to make sense of them. Several researchers, including Clausner (2002), Langacker (1987, 1991) and Talmy (2000a, 2000b), offer a cognitive view of vision and language. Others (Cox, 1999; Keller & Tergan, 2005; Sweller & Chandler, 1994) have found that visualisation functions as important methods and tools because:

1) Visualisation capitalises on several characteristic features of the human cognitive processing system;

2) Visualisation can reduce cognitive load and expand the capacity of an individual's memory for coping with complex cognitive task requirements;

3) Visualisation can enhance processing ability by visualising abstract relationships between visualised elements and may serve as a basis for externalised cognition.

2.3.3.3 The Potential of Visuals for Knowledge Management

It is considered difficult, but still possible, to unleash the power of visuals to work for KM. To promote knowledge conversion (Nonaka & Takeuchi, 1991), a figurative communication style is recommended although this remained unexplored for a long time.

> To convert tacit knowledge into explicit knowledge means finding a way to express the inexpressible. Unfortunately, one of the most powerful management tools for doing so is also among the most frequently overlooked: the store of figurative language and symbolism that managers can draw from to articulate their intuitions and insights (Nonaka & Takeuchi, 1991, pp. 99-100).

Visuals have much potential in KM. For example, Burkhard and Meier (2005) assert that a typical metro station map 'tube-map' visualisation provides an overview and details in one image, it also initiates discussion and thus enables knowledge sharing. Berger et al. (2013) recognise that "visual abstraction has been used throughout history as a technique to communicate information more effectively and more efficiently—highlighting specific visual features while downplaying others" (p. 1).

2.3.4 Implications of Knowledge Visualisation

Visual aids have a long history as amplifiers of human learning capabilities (Akoumianakis, 2011) and as better ways of organisations of knowledge to share

with others (Keller & Tergan, 2005). It is believed that following the publication of *Readings in information visualization: using vision to think* 1999), three main research directions were initiated:

- social visualisation, which seeks to provide informative accounts of the social context in which information is created (Gilbert & Karahalios, 2009);
- information visualisation, which is mostly used in the IT domains (Gilson, Silva, Grant, & Chen, 2008); and
- knowledge visualisation, which tries to exploit the potential of knowledge (Jeong, Chang, & Ribarsky, 2008; Medeni et al., 2011; Wang et al., 2009) .

Confusion over the definition of knowledge and the boundary lines between data, information, knowledge and wisdom bring distortion to the corresponding visualisations. Hays (2010) attempted to employ diagrams to map wisdom, which can be treated as knowledge from the owners or information for others.

2.3.4.1 Definitions of Knowledge Visualisation

This section explores KV that falls *within the scope of this thesis*, it synthesises complementary KV and language, and ends with an evaluation of KV.

KV is one state-of-the-art area that was differentiated from information visualisation and visual communication by Burkhard and Meier (2004); Eppler and Burkhard (2007). In line with Eppler & Burkhard (2007, p. 112), *KV is defined in this research* to mean "all graphic means that can be used to construct, assess, measure, convey or apply knowledge (i.e. complex insights, experiences, methods, etc.)."

According to the framework for KV developed by Eppler and Burkhard (2007), six types of knowledge are proposed: "declarative knowledge (know-what), procedural knowledge (know-how), experiential knowledge or experience (know-why), people-related knowledge (know-who), orientation or location-based knowledge (know-where), scenario-based knowledge (know-what-if) or normative, value-based knowledge" (p. 113). Most of them, specifically know-what, know-who, know-where, and know-what-if are treated merely as information by Ackoff (1999). From another perspective, data and information forms the basis of knowledge, so if KV is used for KM, it is natural to manage data and information at the same time.

KV can help to gain attention (e.g., advertising), inspire recipients (e.g., art), address emotions (e.g., advertising), improve recall (e.g., signs, visual metaphors), or initiate discussions (i.e., satirical comedy) (Burkhard, 2006). ICT tools such as tablet PCs and tablets, mind-mapping, concept mapping or sketching software support digital sketching for rapid knowledge depiction (Eppler & Burkhard, 2007).

KV and information visualisation share the feature that they aim at visualising structures. Researchers have recently begun to employ visualisation techniques with diverse sources and different purposes in mind involving knowledge, information and data. KV was first differentiated from information visualisation and visual communication by Burkhard and Meier (2004); Eppler and Burkhard (2007) While KV and information visualisation both aim to visualise structures, the differences between KV and information visualisation varies in some aspects, such as goals, benefits, content, or recipients (Burkhard, 2005b). KV is differentiated from information visualisation because "these graphic formats capture not just (descriptive) facts or numbers, but contain also prescriptive and prognostic insights, principles, basic assumptions and relations" (Eppler & Burkhard, 2007, p. 113). Ironically some research such as by Hou and Pai (2009), which claimed to be dedicated to KV, used information visualisation objects.

2.3.4.2 Complementary Use of Words and Images

Given that visual representations have advantages and disadvantages, the complementary use of visual and verbal representations seems promising. Kendler (2013) suggests that a combination of text and graphics encourages each medium to play to the unique aspects of the content as a whole. He maintains that graphics is good for communicating specific spatial, physical and structural attributes, but are less capable for abstract concepts. However, Keller and Tergan (2005) argue that too much text causes extraneous cognitive load and too little may cause misunderstanding, so a trade-off between the visuals and text needs to be set when developing the techniques.

In terms of scientific validity, explicit and propositional knowledge were accepted as being key criteria, but the role of conceptual models expressed in a visual format was also highlighted by Worren et al. (2002).

According to Schriver (1997), text and graphic options should be combined so as to achieve the desired communication purpose. Kendler (2013) proposed four types of combination: redundancy, complementation, supplementation, and stage setting.

- **The redundant combination** uses both textual and graphic means at the same time. The combination works when the dual coding of information facilitates multiple connections to the same concepts in long-term memory (Kendler, 2013), but it fails when the redundancy causes viewers to lose interest (Schriver, 1997).
- **Complementary and supplementary options** use the strengths of textual and graphic communication to support each other. This works when one channel is not enough and the other one can be utilised for more efficient communication (Schriver, 1997). As mentioned above, graphics are very capable for communicating specific spatial, physical and structural properties in a clear, concise way but are not so efficient and consistent at abstract concepts, which is the strength of verbal communication (Kendler, 2013).
- **The stage setting** combination provides the receivers or readers with the context and guidance to understand the whole message.

As this research on knowledge sharing will be attempting to use verbal and visual communications together, *the four combination types proposed by Kendler (2013) provide a framework to observe the use of visuals.*

2.3.5 Evaluation of Knowledge Visualisation

Golombisky and Hagen (2010) principle of good design, that form follows function indicates how to evaluate the KV quality. A good design results from a partnership between the forms as material artistry and the functions as the usefulness of the design (Golombisky & Hagen, 2010). This simple principle from the design discipline shows how good graphic design captures attention, controls the eye's movement across the page or screen, conveys information and evokes emotion. Good KV similarly prioritises the utility of imparting the knowledge over the form itself. Despite the great varieties of KV, *the means by which KV achieves its goal is critical to this research*.

Practical evaluation is necessary to ensure that KV can work in the business workplace context. Four aspects are proposed by Desouza and Paquette (2011):

1. Effectiveness: Was the desired result produced?
2. Efficiency: Was it cost-effective?
3. Impact: What value was provided?
4. What best practices should be derived?

These are the general criteria that can provide guidance but currently no accurate metrics for KV exist, since knowledge cannot be quantified. In the information visualisation domain some concepts such as data-ink ratio and chart junk were introduced by Tufte (2001). However Inbar, Tractinsky, and Meyer (2007) argued later that increasing data-ink ratio does not necessarily result in a decrease in response time and an increase in accuracy, as Gillan and Richman (1994) had suggested. Furthermore, prior familiarity with graphs, preferences and a person's level of receptiveness affect the choice of a good graph (Inbar et al., 2007).

Communication science researchers suggest that "an effective transfer of knowledge depends on an effective communication of the content, for example concerning the participants, the transferred message and the used channels" (Meyer, 2008, p. 4). Ellis (2009) points out that **efficiency and effectiveness** are distinct aspects in communication. For example, an email is quick and cheap but it can cause acute problems, while face-to-face communication is the most effective but it takes time and skills. Effective communication only happens when the receiver extracts the exact message that the sender intends to share.

Some similarities and differences in verbal and graphical communication are discussed in the literature. Four basic principles of verbal communication are proposed by Grice (1975): quantity, quality, relation and manner. Grice's maxim of quantity requires neither more nor less communication, maxim of quality encourages true contribution, maxim of relation asks for relevance, while maxim of manner requires being perspicuous. These principles indicate that successful interaction between emitters and receivers needs an appropriate amount of information – not too much also not too little – to be passed on with evidence and

in a sincere manner, while the contents must be related to the topic(s). For verbal communication:

> A word can only serve to indicate that someone else may have a valuable idea—that is, some useful structure to be built inside the mind. Each new word only plants a seed: to make it grow, a listener's mind must find a way to build inside itself some structure that appears to work like the one in the mind from which it was learned. (Minsky, 1986, p. 270)

For graphical communication, Massironi (2002) accepts quantity and manner as containing the right amount of information and having a truthful communicative intent. However, he modified quality and relation into the principle of emphasis/exclusion which implies that "only those aspects that are relevant to a specific communication will be included and emphasised, whereas the others will be neglected" (p. 75). In other words, the format of a graphic, whether a realistic photo or a simple sign, should meet the needs of the communication goals.

2.3.6 Sharing Knowledge and Tacit Knowledge with Knowledge Visualisation

KV is thought to have the power to capture more implicit aspects of personal knowledge that cannot be expressed easily through verbal means, but can be conveyed through graphic analogies or symbols (Eppler & Burkhard, 2007).

The potential for KV to relate with TK comes from an example on facial recognition that was noted by Polanyi (1966):

> We know a person's face, and can recognise it among a thousand, indeed a million. Yet we usually cannot tell how we recognise a face we know, so most of this cannot be put into words. (p. 4)

When an individual sees a face, she is not self-conscious about her knowledge of the configuration of the individual features (eye, nose, mouth, etc.), but she sees and recognises the face as a whole (Engel, 2008).

Although many research studies focus on KV, little attention has been paid to the integration of KV with TK. Because of the intangible form of TK, it is not easy to combine it with tangible KV. Nonaka and Takeuchi (1991) commented:

> To convert tacit knowledge into explicit knowledge means finding a way to express the inexpressible. Unfortunately, one of the most powerful management tools for doing so is also among the most frequently overlooked: the store of figurative language and symbolism that managers can draw from to articulate their intuitions and insights. (pp. 99-100)

2.3.6.1 Share Knowledge via Knowledge Visualisation

None of the approaches or the categories proposed by Clark and Lyons (2010), Horn (1998, 2001), Lengler and Eppler (2007) and Mayer (2009) cover the domains of KM or knowledge sharing. Even though the framework proposed by Eppler and Burkhard (2007) does make some valuable points about KV, it does not focus on knowledge sharing or touch the field of TK sharing.

Representations are "the prerequisite for all communication, all human exchanges of thoughts and ideas" and are thus needed "as a means of expression in order to be able to convey and share our knowledge, ideas, insights and warnings" (Bergström, 2008, p. 221). For example, a tube-map visualisation is basically a visual metaphor made by customizing a well-defined transportation map with complex project information. This method was employed by Burkhard and Meier (2005) to communicate to different target groups and build up a mutual story. As previously mentioned, the tube-map visualisation was found useful by the employees "because it provides overview and detailed information in one image and because it initiates discussion (p. 473)". They also indicated that tube-map visualisation is a powerful metaphor to communicate complex ideas and to build up a mutual story thus being useful to the users.

2.3.6.2 Share Tacit Knowledge with Knowledge Visualisation

TK is often elicited by means of figurative language and symbolism to express the inexpressible. Busch et al. (2001) tried to use concept maps to visualise articulable TK. Zanting, Verloop, and Vermunt (2003) compared the use of interviews with concept mapping in the context of teacher education, and concluded that both instruments can help student teachers to access practical knowledge with each revealing qualitatively different information: interviewing yielded more concrete, practical information while that produced by concept mapping was more abstract. Noh, Lee, Kim, Lee, and Kim (2000) propose using a cognitive map as the main vehicle for formalising TK, and case-based reasoning as a tool for storing cognitive

map-driven TK in the form of frame-typed cases, and retrieving appropriate TK from the case base according to a new problem.

Many attempts to visualise TK using specific visual tools are described in the literature. Busch et al. (2001) attempt to map articulable TK with social network analysis, which can be seen as more like information clustering. Clausner and Fox (2005) propose a framework and toolkit for visualising TK with visual metaphors that represent temporal concepts about geospatial events and their qualitative uncertainties. This has limitations but provides an insightful approach to TK visualisation. Wang et al. (2011) use knowledge maps to accumulate and visualise the TK of teachers on educational assessments, and employed system usage records, questionnaires and interviews to gain insights. Kinchin et al. (2008) propose concept maps to locate tacit dimension of clinical expertise, as concept maps can show the relationships between concepts and "the act of concept mapping also slows reflection on actions that are normally automated and often overlooked" (p. 93). Medeni et al. (2011) propose a TK visualisation framework to support know-where requirements of the organisational knowledge. Visual metaphors are one of the natural visual options to communicate TK, just as linguistic metaphors do for abstract concepts (Clausner & Fox, 2005).

Little literarture (Dean et al., 2008; Eppler & Pfister, 2014; Filstad & Gottschalk, 2010) has been found to notice the industry differences while there is a need to study this field. Most of the research focused in a specific industry. Alony et al. (2007) did their research in the film industry. Minhong, Jun, Bo, Hance, and Jie (2011) conducted surverys and interviews among university students for e-leanring. Lilleoere and Hansen (2011) examined knowledge sharing in pharmaceutical industry. Some other researchers (Dean et al., 2008; Eppler & Pfister, 2014; Filstad & Gottschalk, 2010) explored knowledge management in law inforcement. Chawla and Joshi (2010) examined knowledge management implementation in Indian manufacturing, IT and IT Enabled Services (ITES) and power generation and distribution companies.

From the literature discussed above, it is clear that most study has focused on software and tools for TK sharing. Also, the KV framework and cases by Eppler and Burkhard (2007) only provide general guidance on how to implement KV for TK sharing.

2.4 Chapter Summary

As stated by Wittgenstein (1968), if we really want to understand the meaning of a word or phrase, rather than asking for a definition, we should look at how it is actually used. The same is true of knowledge and knowledge handling. From the discussion of literature around topics of knowledge definitions, KM, TK sharing, and KV, several key points and gaps were identified:

- There are debates and confusion about knowledge and its related terms in the literature, affecting the choice of KM tools. It is necessary to explore how people in real businesses acquire their own definitions and tools.
- TK is hard to express but valuable in multiple ways. It is reported in some literature that TK can be kept as tacit but is still shareable. It is necessary to seek more evidence to confirm this contention.
- Visuals seem promising in KM, knowledge sharing and communication. Although limited literature has explored the integration of KM and KV, no practical research was found to focus on TK sharing with KV. Thus, there is the need to observe how individuals use visuals to share their knowledge and TK.

Chapter 3 : Research Design

This chapter clarifies the research purpose before discussing epistemology, theoretical perspective, and methodology. Procedures for research design, data collection and data analysis follow. The chapter ends by considering the rigour and trustworthiness aspects of this research, Figure 3.1.

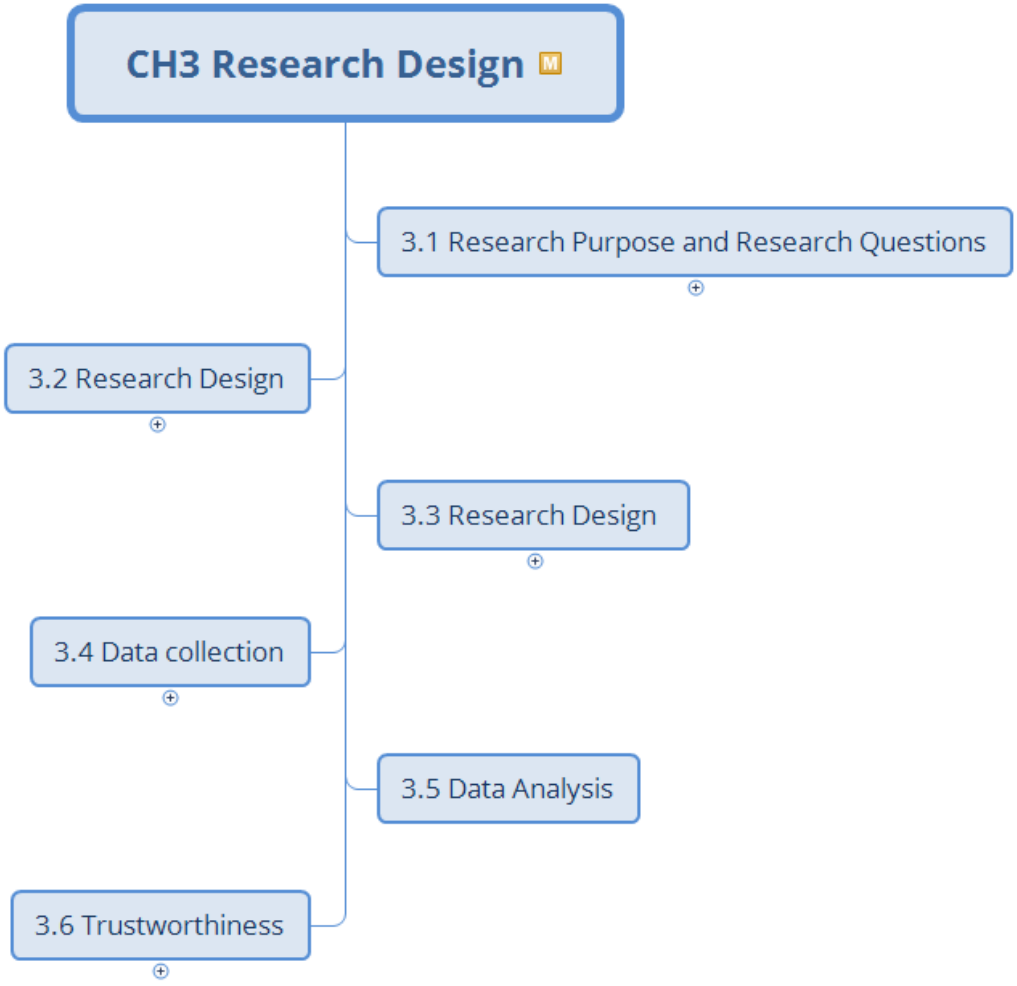

Figure 3.1: Structure of Research Design in Chapter 3

3.1 Research Purposes and Research Questions

This section focuses on research purpose and questions.

3.1.1 Research Purpose

This research has three principal purposes. The first purpose is to gain insights into the knowledge sharing processes employed by experts in business workplace contexts, and to investigate the critical elements involved in the knowledge sharing process for individuals, groups, and organisations. This research has the ultimate intention to help businesses better utilise the potential of their experts' knowledge, and help novices learn faster.

The second purpose is to explore how people use knowledge representation; specifically, visual representation rather than its pure verbal counterpart. It will also investigate how these two representations complement each other, and how people use representation tools to share their knowledge and TK more effectively. This research has the ultimate intention to help people realize the importance of visual communication and help them find appropriate toolkits to use.

The third purpose is to rigorously investigate the nature of knowledge exploitation and KV, and thereby contribute to the academic literature. Review of the literature shows there has been substantial research on KV in combination with knowledge management (e.g., Eppler and Burkhard (2007)), but relatively few studies have examined KV effectiveness in combination with TK. Researchers and managers seem to be struggling to find a way to build and share TK across different locations. This research hopes to fill this gap, and to complement and extend traditional approaches to TK sharing, by introducing KV as an effective communicative tool.

3.1.2 Research Questions

Literature gaps gave pointers to the appropriate research questions for this research. Debates on the definition of knowledge affect the choice of knowledge representations, thus providing different perspectives of knowledge exploitation. To be consistent, a combining of related definitions, concepts, and toolkits are needed from the literature for practical use. The evident confusion and debate around definitions of knowledge and knowledge management motivated the researcher to ask one fundamental research question.

The research question, plus its sub-quesitons, focuses on knowledge visualisation and asks how and why people employ KV to facilitate knowledge sharing:

RQ: How can visuals facilitate the tacit knowledge sharing process?

- How do professionals share their knowledge with others, especially the tacit part?
- What kinds of visuals are employed to aid communication?
- How do people use visuals to facilitate the knowledge sharing process?
- What are people's purposes for knowledge visualisation in terms of knowledge sharing and communication?
- How do people evaluate the effectiveness of knowledge visualisation for knowledge sharing?
- Why does knowledge visualisation sometimes fail to facilitate knowledge sharing?
- How can knowledge visualisation be used to facilitate tacit knowledge sharing? and
- How can knowledge visualisation help novices grow into experts?

3.2 Research Design

To answer the research questions, research epistemology, paradigm, methodology and method were considered, in accordance with a framework by Crotty (1998). Chenail, Duffy, St George, and Wulff (2011) describe this as an effective tool that makes clear the perspectives involved since an increasing trend is evident of "several epistemological positions, quite a number of theoretical stances, many methodologies, and almost countless methods" (Crotty, 1998, pp. 4-5).

The four elements: epistemology, theoretical perspective, methodology, and method. inform one another as follows (Table 3.1) :

- The epistemology informs the theoretical perspective;
- The theoretical perspective informs the methodology and thus provides a context for the process, and grounds its logic and criteria;

Table 3.1: Sample List for Research Design

Epistemology	Theoretical prospective	Methodology	Methods
Objectivism **Constructionism** Subjectivism (And their variants)	Positivism (and post positivism) **Interpretivism** • Symbolic interactionism • Phenomenology • Hermeneutics Critical Inquiry Feminism Postmodernism etc.	Experimental Research Survey research Ethnography Phenomenological research Grounded theory Heuristic inquiry Action Research **Case Study** Discourse Analysis Feminist standpoint research Etc.	Sampling Measurement and scaling Questionnaire **Observation** (Participatory/non-participatory) **Interview** Focus group Life history Narrative Visual ethnographic methods Statistical analysis Data reduction Theme identification Comparative analysis Cognitive mapping **Document Analysis** Content Analysis Etc.

Source: Crotty (1998, p. 5) and Collis and Hussey (2014)

- The methodology informs the research method(s) to use. Here, methodology refers to the strategy, plan and action, process or design that informs the choice and use of research method, and links them to the research outcomes.

For this research, case study was treated as research methodology rather than research method, which is a stance that is supported by Collis and Hussey (2014).

In each of the following sections, a brief literature review is followed by description of the justification of 'method' fit with the particular needs of this research.

3.2.1 Research Epistemology

Epistemology deals with the relationships between knowledge and human beings. Basically there are three research epistemology: Objectivism, Subjectivism, and Constructivism (Crotty, 1998).

Constructivism is appropriate for this research for several reasons. Firstly, constructivism provides the guidelines this research follows to interpret and gain insights from first-hand data. Constructivism assumes that the meaning of experiences and events are constructed by individuals (Charmaz, 2006). This research explores knowledge, TK, and knowledge representatives, and it is accepted that knowledge can only exist in the knowers' mind and is constructed rather than transferred by the knowledge user. Every learning and sharing activity is a knowledge constructive process.

Second, constructivism provides a similar construction of meaning by the researchers as "their interpretation of the studied phenomenon is itself a construction" (Charmaz, 2006, p. 187). Researchers can deepen their knowledge by employing the constructivism to observe the specific phenomenon.

Constructivism is also one of the approaches researchers tend to invoke to answer how- and why- questions such as the research questions of this research. *This research will enquiry why and how tacit knowledge will be shared with the help of knowledge visualisations, making constructivism appropriate for this thesis.*

3.2.2 Research Paradigm and Theoretical Perspective

Paradigms are broad views of perspectives of something (Taylor, Kermode, & Roberts, 2006). To be specific, they are "patterns of beliefs and practices that regulate inquiry within a discipline by providing lenses, frames and processes through which investigation is accomplished" (p. 460). The choice of paradigm is important as it addresses questions about what is taken to be important, legitimate, and reasonable (Patton, 2015). The paradigm reflects the researcher's choice on the nature of knowledge and philosophies and assumptions about the world (Collis & Hussey, 2014), which then influence the researcher's standpoints on research methodology and methods. There are two main paradigms: positivism and interpretivism.

This research is based on the *interpretive paradigm* for three major reasons. Firstly, interpretivism provides a baseline for this research. The research focuses on TK, which is thought to exist and work in human minds. TK has a subjective nature which corresponds to interpretivism. Positivism originated from the natural sciences and is characterised by the assumption that social reality is singular and

objective. Knowledge is derived from positive information as it can be scientifically verified and will not be affected by the act of investigating it (Collis & Hussey, 2014; Creswell, 2003). Research with a positivist paradigm often involves a deductive process with a view to providing explanatory theories to understand social phenomena (Collis & Hussey, 2014). In contrast with positivism, which attempts to measure social phenomena, interpretive research tends to explore the complexity of social phenomena with an emphasis on words rather than numbers as the major elements of research data (Chen, 2010; Collis & Hussey, 2014) .

Secondly, the interpretive method also enables the researcher to qualitatively study the research question *how* in greater depth. It is accepted that there is an objective world outside human minds, intercommunicating with the human inner subjective world, and this should be interpreted by the researchers. This research approach is more exploratory than confirmatory, and is oriented more toward theory building than theory testing.

Thirdly, interpretivism fits the research purpose better. This research asks the *how* and *why* questions which should be answered inductively rather than deductively. An interpretive approach can cope better with this with this purpose than positivism can. To ensure a strong research design, researchers must employ a research paradigm which is congruent with their beliefs about the nature of reality (Jane Mills, Bonner, & Francis, 2006). Interpretivism is the researcher's belief about the nature of reality and, since the researcher adopts interpretivism as a personal belief, again it is better to follow this approach as the research paradigm.

3.2.3 Research Methodology

Research methodology concerns the philosophical question of how to generate knowledge by linking the method choices to the desired outcomes. According to Crotty (1998), research methodology refers to "the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods of the desired outcomes" (p. 3). In other words, a methodology encompasses a body of methods (Collis & Hussey, 2014).

Although they are all consistent with the interpretivist research paradigm, *case study*, rather than action research and other methodologies was chosen for this research.

Case study is appropriate for this research for several reasons:

Firstly, one of the main strengths of case study is that this approach is a research strategy when a contemporary phenomenon can be studied in its natural context (Yin, 2009, 2014). To understand how and why people use visual representations to share their knowledge, this research is mainly conducted in a contemporary and natural setting.

Secondly, case study is particularly suitable when theoretical knowledge of a phenomenon is limited or when the need for capturing context is important. This research attempts to identify how TK can be effectively shared between people to achieve organisational performance, and seeks to investigate the effectiveness of KV in TK sharing. Because it is also very important to capture the context in a natural way, case study research is particularly appropriate for this present research.

Thirdly, case study has the potential to provide more in-depth understanding of the TK sharing process than a quantitative survey. TK sharing processes require a breadth and depth of analysis, which could be difficult to obtain, using statistical methods or other positivist scientific approaches (McQueen & Chen, 2010).

Finally, multiple-case study is an appropriate research strategy for the present study. Evidence from multiple cases is often considered more convincing, and the overall study is regarded as being more powerful (Yin, 2009). Multiple cases also broaden understanding of the experiences and practices chosen by a variety of organisations. They also strengthen the research findings by allowing investigation of a phenomenon in diverse settings, which enables cross-case analysis and comparisons (Benbasat, Goldstein, & Mead, 1987; Eisenhardt, 1989).

3.3 Research Sample

Figure 3.2 illustrates the replication approach to multi-case studies that was adopted for this research.

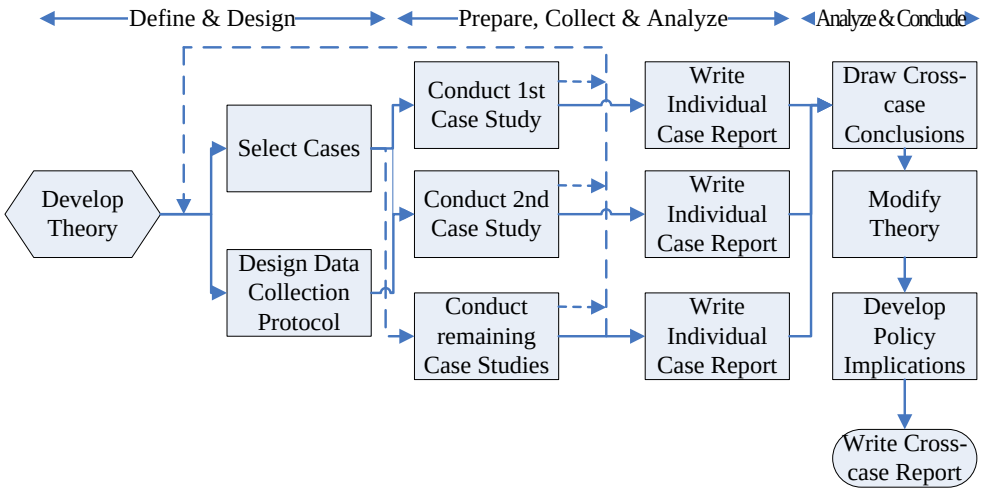

Figure 3.2: Approach to Multi-Case Studies

Source: Yin (2009)

3.3.1 Number of Cases

The research employed semi-structured interviews, non-participatory observation and document review to collect data from 35 participants in 19 organisations and eight industries. These mostly service-based industries included management consulting, education, scientific services, law consulting services, software services, architectural services, and speaking clubs. More details are given in Appendix A. A minimum of two cases was carefully selected in each industry. In the scientific service and speaking clubs, the researcher spent several months exploring the rich data streams.

Literal replications were found within the scientific services (four similar groups) and within architectural services (three cases). At least seven cases from scientific services and architectural services supported the theoretical replications with differences of patterns.

3.3.2 Unit of Analysis

Two approaches to the unit of analysis were identified by Yin (2009): holistic and embedded design. A holistic design can be adopted at an abstract level when sub-units cannot be found, while an embedded design often contains more than one sub-unit of analysis. This research, on top of multiple cases, has followed the embedded approach (multiple units of analysis) because this research looks at both the individual and industry levels of knowledge sharing. The basic analysis unit is the

industry within which the participants are working. The sub-units are the participants who are involved with the actual knowledge sharing process. The analysis of industries can provide rich insights into the common/distinctive characteristics of each industry from a higher-level perspective. Conversely, details about individual knowledge sharing can be found from analysis of the sub-units.

3.3.3 Case Selection

Cases and sites were selected using the following criteria:

- The organisation/participants are knowledge/skill-rich;
- The participants use visual representation as one of their communication channels, and
- The participants are willing to participate in the study.

This research chose 19 sites for general interviews and in-depth observations. The sites comprise: management consulting (3 sites), education (2), scientific services (3), law consulting services (2), manufacturing (4), software services (1), architectural services (2), and speaking clubs (2).

Each industry has its specific knowledge/skill although not every industry favours visual representation, Appendix A.

It is also noted that every indidual professional is an expert in a specific area while a novice in some other areas. Keeping this in mind, the researcher has not tried to lable the participants into experts or novices, but engaged them with a specific topic and decided the expertise levels. The differences between novices and experts are also surmarized from this treatment.

3.4 Data collection

For this research, three techniques were employed as the main collection methods: document review, semi-structured interview, and non-participant observation. Data was collected from multiple sources to generate detailed information and triangulation support. As suggested, multiple sources of data can increase the reliability of research results.

This research used two combinations of data collection techniques to achieve the

broadness and depth. The first combination of document review and semi-structured interview took less than 1.5 hours in total to achieve the required broadness of research data. Before seeing the participants for the first time, the researcher always tried to find related materials such as publications, a LinkedIn Profile, and examples of visual representations. During the interviews, the participants were asked how and why they chose the visuals in their publications and projects.

The second combination focused more on depth by requesting observations and document reviews as well as a semi-structured interview. This combination was always longer than 2 hours, and in some cases as long as 6 months. Participants were encouraged to draw/use their own pictures during the interviews and observations. At the same time, they were asked how and why they chose visual ways to share their knowledge.

3.4.1 Document Review

Document review provides important background information about the employment of visual representations without any interference by the researcher. It shows the natural choice of visual representations from the participants, and helps the researcher to better organise follow-up interviews and understand the feedback from the participants. Document reviews included inspection of participants' own publications, manuals related to their jobs, and the outcomes after sharing their knowledge. Many sources of documents elicited a good understanding of how people use visuals for knowledge sharing and communication. For example, some participants were asked to show the whiteboards which they had used recently to facilitate their discussion and others were interviewed with their published journal articles containing graphs/pictures.

There are varied approaches to employing KV and this research aimed to explore the taxonomy. Hence, there were no limitations placed on the types of artefacts that were examined. Of course, not all the participants had their own publications. For those that did, bringing their articles to the interviews encouraged them to elaborate on their experiences with KV. Some evidential documents were generated during the interviews.

3.4.2 Semi-Structured Interviews

The semi-structured interview provides flexibility as it is balanced with structure and the quality of the data obtained to conduct a research project (Gillham, 2005). Some of the research questions were formalised and prepared to encourage the interviewee to talk about the main topics of interest (Collis & Hussey, 2014).

The interview questions are outlined in Appendix B. The questions were designed to collect general perceptions of basic terms such as knowledge, KM, KV, and TK, before moving to personal perceptions and experiences with visual representations. Story-telling and visual techniques from the participants were encouraged during the interviews.

Some questions such as the ones on "learning style" or "mental imagination" are warm-up questions which do not contribute to the research questions directly. They only serve the purpose of touching base with the participants and connecting them with this research. Additional questions were put to the interviewees when the following conditions suggested by Easterby-Smith, Thorpe, and Jackson (2012) were met:

- It is necessary to understand the personal constructs (sets of concepts or ideas) used by the interviewee as a basis for his or her opinions and beliefs;
- The research purpose is to develop an understanding of the respondent's world so that the researcher might influence it (for example through action research);
- The logic of a situation is not clear; and
- The subject matter is highly confidential or commercially sensitive, or there are issues about which the interviewee may be reluctant to be truthful.

Semi-structured interviews fit this research well. It is necessary to understand how people perceive their knowledge and TK to develop an understanding of their innate world. The logic behind the choice of visual tools is not always clear and the participants may be unaware of the correspondence of their knowledge with their choice of visual representation(s).

The research data also has a certain level of confidentiality and commercial sensitivity due to its origination from within real businesses.

3.4.2.1 Story-telling technique

This research on knowledge and TK has the natural need to take advantage of the power of stories. Stories have the potential to transmitting TK, and researchers can use them to support discussion and data analysis (Kosara & Mackinlay, 2013). By encouraging participants to tell their stories, the researcher can gather the data in which TK is embedded and make the interviews consistent by allowing the interviewees to put their real experiences into a flow of articulation.

The researcher motivated the participants to tell their own stories. For example, if the participants had an interesting point, they could be asked "*Can you please elaborate more about this?"* or the researcher would ask for more information on what, when, where, why and how so that all the questions could be formed into a story afterwards.

3.4.2.2 Visual Techniques Used During the Interviews

Visual techniques provide reviewability and revivability, thus facilitating the collective refinement of the TK elicited in the research encounter (Comi & Eppler, 2014). Adopting this conviction, this research employed a variety of visual techniques:

- Notes were taken in a visual way. During the interviews, the researcher took notes on all the key points from the participants. The notes were organised into a radial mind-mapping structure, starting from the participants' information to main topics and sub-topics and key points. For example, Figure 3.3 shows the interview with participant A302 on May 1st, 2015. The topics covered include: the participant's job, his publications used for knowledge sharing, his perceptions about knowledge, his experience with knowledge building processes using visuals, introduction to new trials and possibilities, plus some other opportunities. Key points were captured around the sub-topics, which provide guidance for further analysis of the research data.

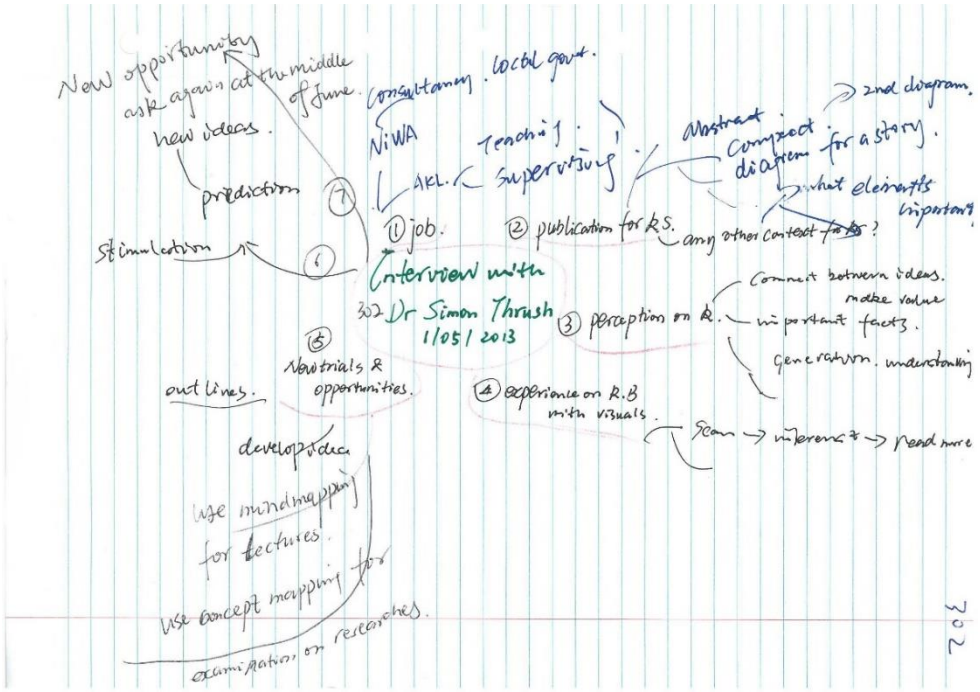

Figure 3.3: Example of Notes Taken with a Mind-mapping Technique

- Participants were encouraged to draw while they were being interviewed. As the researcher is mostly an outsider to the fields of the participants, it could be difficult to understand what the participants were trying to express. By encouraging the participants to draw, if they thought that would be helpful, the researcher experienced easier communication. For example, one participant drew on a glass board to show his utilisation of visuals, as a second channel of communication.
- The researcher also took along relevant pictures to the interview so that, if the participant was willing to draw on them, they could easily do so (this then became part of the research record). For example, during the preparation to interview participant A802, the researcher searched online for the products he may be involved with, and collected relevant pictures. For example, Figure 3.4 was grabbed as a screenshot from a YouTube™ video and printed with other documents in preparation for the interview. At interview it was shown to the participant who, when he found it hard to explain a point, he asked for a pen and began drawing on that picture. For the participant, it seemed easier than just using verbal communication. For the researcher, it was much easier than just relting on words and imagination.

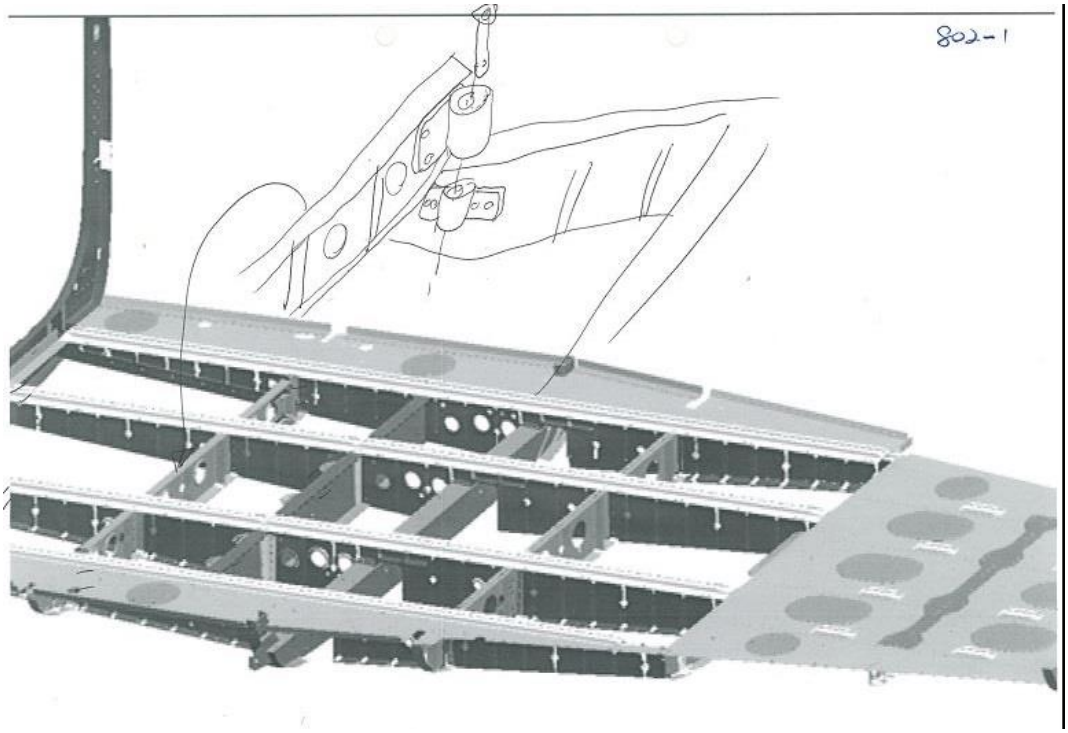

Figure 3.4: A Participant's Annotations
Source: Participant (A802, 248:1)

- Visual clues were collected during the interviews. The researcher observed the participant's workplace if possible, and asked for more evidence, usually photos. Images of the whiteboards and the environment were also recorded. Such visual cues are helpful to understand the participants' work context. For example, Figure 3.5 combines two photos that the researcher took in a participant's office. Although the whiteboard was not being fully used, the wall near the whiteboard and the pin board were full of printed drawings and photos. This display of visual information motivated the researcher to explore and highlight potential topics for discussion.

Every interview was recorded via manual notes and audio recordings and then transcribed into digital text for analysis.

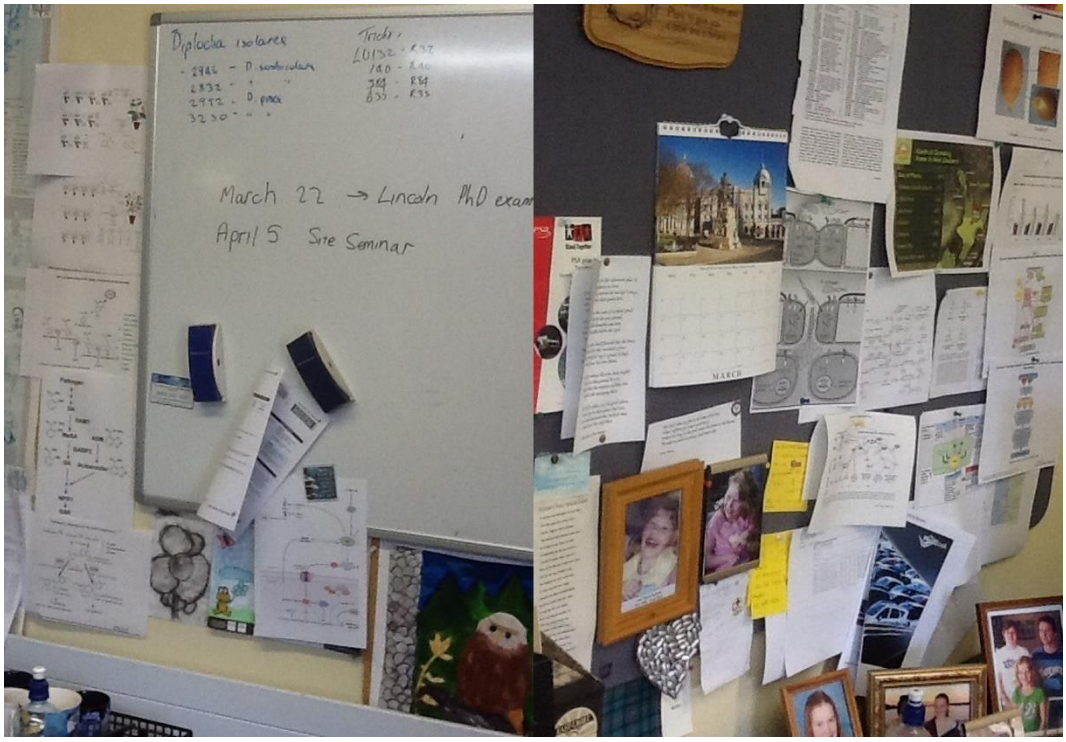

Figure 3.5: Collecting More Visual Clues from the Environment

Source: Participant (A503, 50:2)

3.4.3 Non-Participant Observation

For this research, non-participant rather than participant observation provided a chance to better understand how the participants chose the visual tools to help them share their knowledge. Observation is generally regarded as an unobtrusive method for achieving deeper understanding of a phenomenon and being able to develop detailed stories to describe the phenomenon (Trochim & Donnelly, 2007). As the most common type in business research, non-participant observation allows the researcher to observe and record people's behaviour without being involved (Collis & Hussey, 2014).

Four participant roles for the researchers are identified by Gold (1958): complete observer, participant-as-observer (more observer than participant), observer-as-participant (more a participant than observer), or complete participant. In this study, the researcher adopted the role of complete observer, observing as a fly on the wall (Johnston, Leach, & Liu, 1999) without any queries or interaction with the research participants.

The reason for choosing non-participant observation is twofold. First, English is not

the first language for the researcher himself, so it would be difficult for the interactions between participantory activities. Second, this research concerns the language of the discipline which needs more focus on the engagement of the participants rather than the researcher.

Non-participant observation was requested when the researcher judged that more detail might be gained with groups of participants. For example, when the researcher learned that organisation A8 would be holding a meeting related to recent technical problems, this was perceived to be a good opportunity to discover how people share their knowledge around a topic and encourage one another to seek a solution. Observations during the meeting collected rich information on how employees use sticky notes to become better organised, inspire creativity and achieve innovation. In organisation B1 the researcher remained in situ over several months to observe how the members of a speaking club integrated visual techniques with their speaking skills.

The non-participant observations were recorded via notes, photos and audio recordings.

3.5 Data Analysis

The data collection and analysis process should always be integrated, which means that once the data collection begins, analysis should also begin. Data analysis was facilitated with the aid of a qualitative software program—ATLAS.ti™.

3.5.1 Research Data

The data collected from this research included 35 general interview and document reviews, plus 10 observations (Appendix B). To maintain confidentiality, codenames (A/B + a sequential number) are used. For example, A3 is referring to the third participating organisation. Hence, A302 refers to the second participant in organisation A3.

A strong difference was noted between the speaking club and the other organisations due to the simple fact that speaking clubs are naturally more strongly language relevant. Essentially, the speaking club activities helped the researcher define the scope of the main study. To show the difference, the speaking clubs are classified as B-type organisations while all the other organisations studied are

classified as A-type organisations. No further categorisation was deemed to be necessary.

A pilot study with a local public speaking club was used to observe how participants typically take notes, and how they refer to their notes when delivering evaluations. In this club, members develop their speaking and leadership skills by participating in a speech or an evaluation. Learners may start with a certain objective, for example, trying to speak before the audience, or integrate body language successfully with their presentations. They will read manuals or articles related to their objective (that is, reading the EK of others and preparing conceptual knowledge). The critical part of skill acquisition is to share speaking skills via evaluation. To do this, an evaluator takes notes, synthesises the notes into a speech, and delivers it before an audience. These actions happen in a stressful situation which pushes the evaluator to take notes quickly, synthesise them, and organise the whole message into a proper speech with a time limitation.

The general interviews cover eight industries. To gain a broader perspective, law consultation management consultation and speaking clubs were included. Education and software industries were included to explore people's knowledge perception and choices. Special emphasis was placed on scientists and architects, since scientists were thought to pay more attention to EK while architects were thought likely to pay more attention to their TK.

3.5.2 Data Analysis Strategy and Techniques

Thematic approach (Braun & Clarke, 2006) was employed to analyse the collected qualitative data. The approach provides the flexibility for identifying, analysing and reporting patterns (themes) in the research data. Furthermore, the approach requires the researcher to be familiar with the participants and the context. This was achieved by viewing their profiles before meeting with them, and by the researcher using his own background in management and engineering to better understand the participants and their statements.

From conducting the interviews, the researcher learned much about the different practices in the organisations, the rationale for why things happen as they do; and about the different contingencies faced by different personnel; and their varying attitudes to the procedures. Some aspects the researcher understood quite well and

could write up immediately (although to do so would involve pulling the data together, and organising it into distinct parts). Other aspects required more work.

Cognitive mapping as suggested by Collis and Hussey (2014) was used during the data collection and analysis process. This technique extends the researcher's construct theory and develops a network diagram to help the researcher understand the concepts. Cognitive maps took the form of mind-mapping diagrams (Figure 3.3) as the interview notes were organised into these during the data collection stage. During the data analysis stage, the diagrams were incorporated into the concept maps (Figure 3.9) as built in the analysis software.

Computer-assisted analysis was used, which is coherent with the common iterative process of continuous "reflection of the data, asking analytic questions and writing memos throughout the study" (Creswell, 2003, p. 190). ATLAS.ti™ (Version 7) was used to analyse the data. This is the software tool which Friese (2014) regarded as being "especially suited to making the thinking part of qualitative data analysis visible" (p. 14). ATLAS.ti™ was very helpful to store, organise, code, and search all the research data, which consisted of interview transcriptions, observation notes and photos.

3.5.3 Data Analysis Process—Phases of Thematic Analysis

Six phases of thematic analysis are proposed by Braun and Clarke (2006): familiarising with research data, generalising initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the reports.

3.5.3.1 Familiarising with Research Data

Several actions were taken to become familiarised with the research data. The researcher prepared the interviews beforehand and took mind-mapping notes during the interviews. After the interview, the researcher collected all the materials into ATLAS.ti™, and then began to transcribe the audio records; reading and re-reading the data. At the same time, initial ideas were noted into memos within the software.

Different types of documents with categories were collected into 'Primary Doc Manager' in ATLAS.ti™, Figure 3.6. The documents include the audio recordings, transcriptions, notes, examples, and images. All records are categorised with industries and case numbers to make it easy to analyse the data within or between

different cases and industries. The panel at left shows the categories, such as the industries and case numbers. The main part of the window shows the ID, name, and media types of the documents. In Figure 3.6, organisation A1 has four documents inside the repository. The first one with ID P3 is the audio recording, the second one with ID P4 is the transcription, and the last two are the pictures provided by the participant.

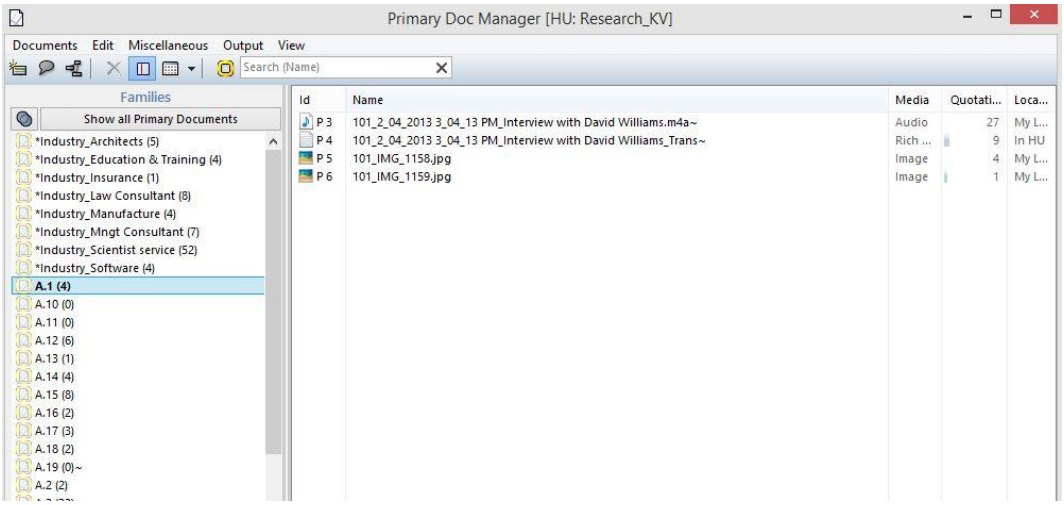

Figure 3.6: Documents stored in Primary Doc Manager in ATLAS.ti™

3.5.3.2 Generating Initial Codes

The hierarchy of the segments in ATLAS.ti™ follows the order document-quotation-code-theme-network. After importing the data into ATLAS.ti™ and reading it, the researcher started on the process of noting and collecting interesting segments of data, developed codes inductively and worked very closely with the data, applying descriptive and initial coding (Saldaña, 2013). The materials were digested into segments and re-organised into categories.

Compared with the traditional pen-and-paper approach of coding, using software provides more possibility and flexibility to take advantage of the research data and therefore facilitates data analysis (Friese, 2014). More than 400 codes were developed in this research. A screenshot of the code list created by ATLAS.ti™ is provided in Figure 3.7. But benefiting from the software does not means the intellectual effort from the researcher. Working with software needs not only researchers' capability on research but also skills on software.

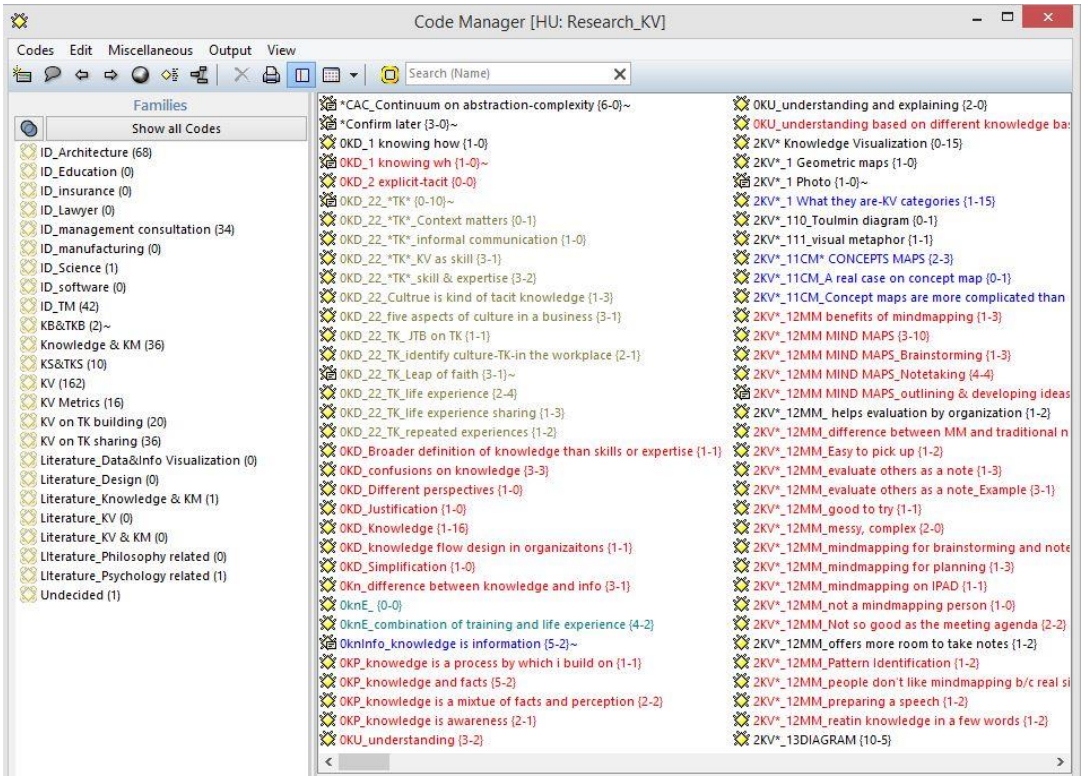

Figure 3.7: Screenshot of the Code List Developed from this Research

Within ATLAS.ti™, different documents have varied coding steps. The texts and pdf documents are coded directly. Audio records need to be transcribed into texts before coding could begin. Graphical segments can be coded and attached to their source, and comments, quotations, and codes also attached for further analysis.

3.5.3.3 Searching for Themes

Themes were developed by collating codes and gathering all relevant data. After the initial coding stage hundreds of codes were generated; each one linked with segments and other resources such as other codes or a memo. The numbers behind the codes in ATLAS.ti™ show the frequency and linkages to other codes. For example, the code "0KD_22_TK_life experience {2-4}" indicates that the code has been linked to two segments and other codes four times.

The researcher reviewed all the coded segments, the relevant research data, and adjusted the code hierarchy. To review the coded segments, double-clicking on a code will lead the researcher into the Code Manager, which has a list of all the coded segments, Figure 3.8. Then, the researcher reviews the relevant parts of the research data, including audio recordings and photos. After the reviews, the researcher can decide to develop more sub-codes under a leading code. For example,

in Figure 3.8, 0KD_22_*TK* {0-10} was used to create a leading code. All the codes can be included in a Code Family.

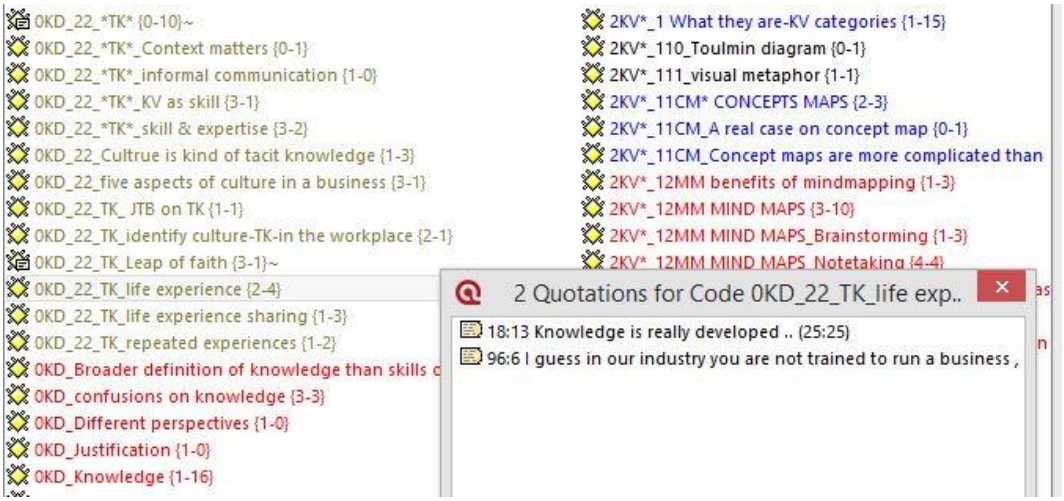

Figure 3.8: Example of Coding in ATLAS.ti™

3.5.3.4 Reviewing Themes

Themes are reviewed by checking if they work in relation to the categories and the entire data set. Categorisation and linkage provides rich information to reveal the meaning of data. A useful feature of ATLAS.ti™ is its network function. A network of the relevant codes can be developed and linked in ATLAS.ti™, Figure 3.9. For example, the code 0KD_22_*TK* {0-10} is a leading code for all the sub-codes (0KD_Knowledge, TK_Tacit knowledge, 0KD_22_TK_life experience, etc.) into which more details and categories are divided. The networking workspace can accelerate thinking by providing an intuitive way to reflect on what the data has captured (Friese, 2014). As can be seen, the network is basically a concept map, which is one of the KV formats studied in this research.

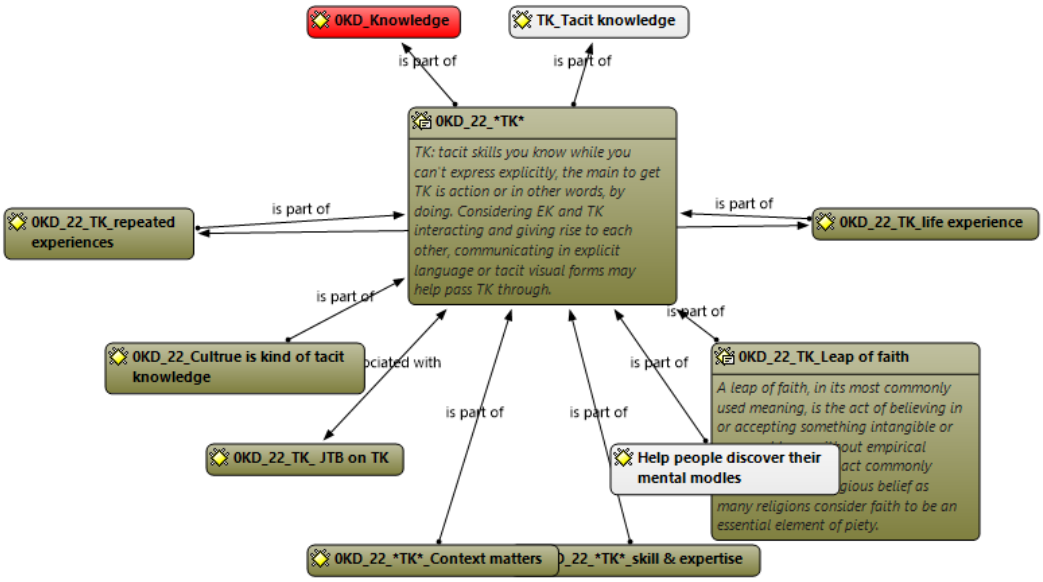

Figure 3.9: Example of Coding Network in ATLAS.ti™

3.5.3.5 Defining and naming themes

Each theme was examined more than once to see what narrative lay behind it and its specifics properties. At this stage, it was possible to read the back stories and the scope of each theme. As data analysis continues, several descriptive codes with low frequencies accumulated. Code families were then generated and set up as a container and a filter, Figure 3.10. These enabled the researcher to focus on the individual consequence codes and sort them by changing the names of code labels (Friese, 2014). Also, codes containing similar content were merged as one code or into a common higher-aggregated code label. For example, in Figure 3.10 the code 0KD_22_*TK* {0-10} sums 12 sub-codes with 36 segments.

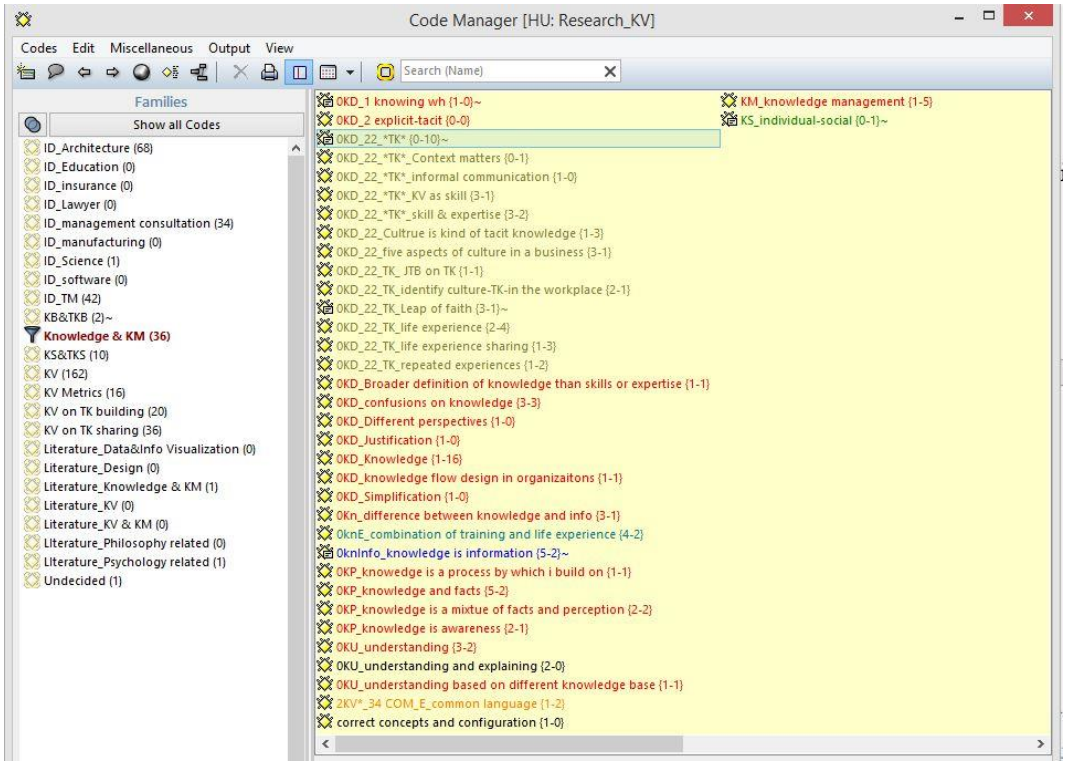

Figure 3.10: Example of Code Families in ATLAS.ti™

3.5.3.6 Producing Reports

After coding, the next step is to examine the research data with the research questions and the literature in mind.

Creating Research Memos

Research memos in ATLAS.ti™ provide a good place to reflect on what had been captured, what could be developed, and possible directions for further analysis during the data analysis process (Friese, 2014). Research memos were developed into several types: analytical, commentary, theoretical, and methodology, Figure 3.11. Each type serves a specific purpose. Analytical memos are used mainly for memos on research findings. Commentary memos keep comments and discussions. Theoretical memos collect and compare literature and research findings. While methodology memos justify research method and design. As the report writing began, research question memos facilitated the idea generation process. It was also helpful to link the memos with related codes and/or other memos.

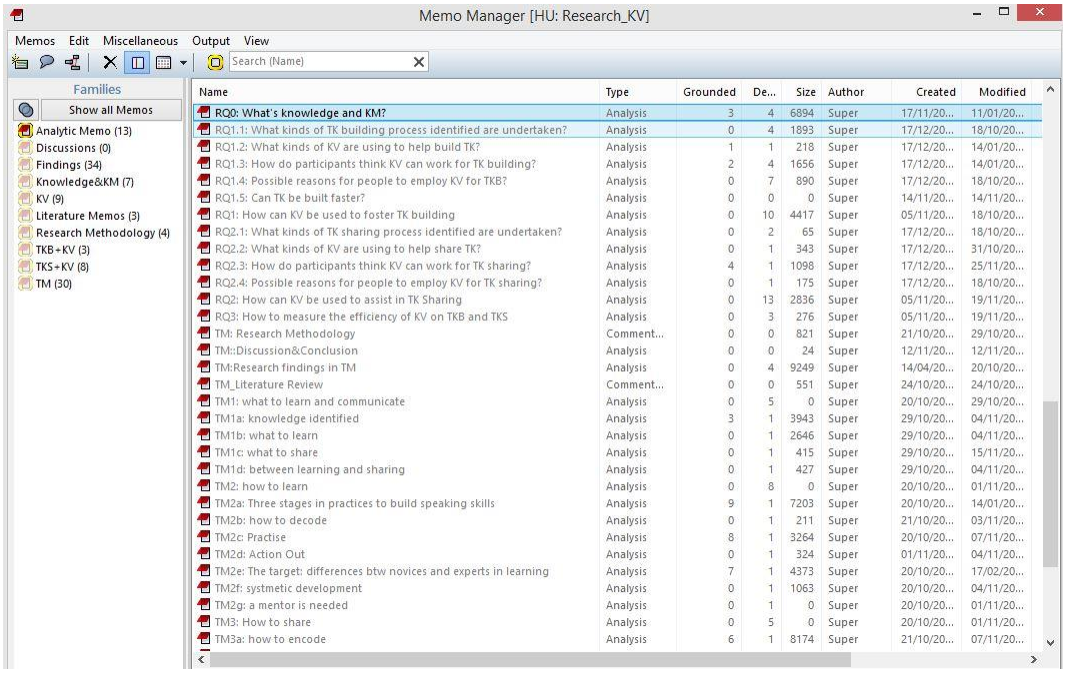

Figure 3.11: Research Memos Created for this Research

Writing is Thinking: The Integration of Memos and Writing:

Memos and diagrams are more than just repositories of thoughts (Friese, 2014). They are working and living documents as the researcher uses the memos to write each finding and then combines the findings into categories. The act of writing memos and drawing diagrams forces the researcher to think about the data, and synthesise what has been learnt from the literature with the data. The thinking process worked well with data analysis, which is important for deep data analysis (Corbin & Strauss, 2008). In addition, writing was found to be the ideal way of clarifying how far the research has attained clear understanding and how coherent the ideas are (Gibbs, 2005). It is also important to mention that keeping an eye on the research questions was part of the thinking process (Friese, 2014). However, as the analysis continued, many codes were generated and the coding strategy varied from that of the initial coding. As Friese (2014) had suggested, the thinking phase started to lead the researcher's strategy.

Writing memos is a main activity for the research. Memos were classified into analysis, methodology, and commentary types that concern ideas, diary and topics. Each memo also has a category for the researcher to organise as discussed earlier.

3.6 Research Trustworthiness

Four aspects can be checked to evaluate the validity and reliability of the qualitative data: credibility, transferability, dependability, and conformability (Lincoln & Guba, 1985). Moreover, the trustworthiness of the qualitative data analysis can be improved by using software, specifically ATLAS.ti™ (Ahmad-Tajuddin, 2013), which was employed for this research.

3.6.1 Credibility

Credibility is used to ensure that the research is conducted in a correct manner (Collis & Hussey, 2014) and there is confidence in the truth of the findings (Lincoln & Guba, 1985). Three tactics were identified by Collis and Hussey (2014) to increase the credibility of case studies: prolonged engagement, triangulation, and peer critique.

Prolonged engagement requires the researcher to spend enough time with the participating site (Collis & Hussey, 2014). In this research, the researcher spent one year on participant observations, interviews, and document reviews at the research sites, including eight months of interviewing 35 interviewees in 8 industries to make sure full understanding of the phenomena had been achieved. Multiple data sources and collection methods are recommended by Collis & Hussey (2014) to provide a more complete and contextual portrait of the subject with the triangulation of data. In this research, participant observation, semi-structured interview, and document review were used. Lastly, peer critique in the form of peer debriefing by colleagues on a continuous basis to ensure the subject is on the right track is recommended by Collis & Hussey (2014). This was undertaken by the researcher in this research in the form of supervisor and colleague critiques and reviews.

3.6.2 Transferability

Transferability concerns the research findings generalisability to similar situations(Collis & Hussey, 2014) and applicability in other contexts (Lincoln & Guba, 1985).

To achieve high transferability, this research employs case studies to achieve good breadth and depth of research. Gathering data from 35 participants in 19

organisations and eight industries provides the possibility to generalise the research outcomes to similar situations.

3.6.3 Dependability

Dependability asks "whether the research processes are systemic, rigorous, and well documented" (Collis & Hussey, 2014, p. 182) and requires that the findings should be consistent and possible to be repeated (Lincoln & Guba, 1985). A pilot study and participant review can be used to increase dependability (Straub, 1989; Yin, 2009).

In this research, pilot interviews were employed to test the reliability of the semi-structured interview questions. Utilisation of the qualitative analysis software—ATLAS.ti™—also increases the dependability of this research.

3.6.4 Conformability

Conformability determines whether the same results can be obtained by other persons following the same research process (Collis & Hussey, 2014). It shows a degree of neutrality, or the extent to which the findings of this study are shaped by the respondents rather than the bias, motivation or interest of the researchers (Lincoln & Guba, 1985). Yin (2009) proposed that a chain of evidence can be used to increase conformability.

In this investigation, the interview questions were structured with the aid of a similar outline, provided in Appendix B. The interview question outline enforced similar structure and guidance during the interviews with different participants. In addition, ambiguous questions were previously tested and revised through a pilot study. In addition, a chain of evidence from publications, photos, notes, audio records, and cross-interviews has been presented, which all help to assure high conformability.

3.7 Chapter Summary

This chapter reviewed the design of this research. Section 3.1 described the purpose and research questions. Section 3.2 discussed candidate approaches from the perspectives of epistemology, paradigm, and methodology, and justified what was chosen for this research. Section 3.3 emphasised the design and justified a case study approach via consideration of case numbers, unit of analysis, and selection of

sites. Section 3.4 illustrated the data collection techniques and included some illustrative examples to show the details. Section 3.5 offered a big picture view on what data was collected, the strategy used for data analysis, and the range of qualitative analysis offered by ATLAS.ti™. In section 3.6 the trustworthiness aspects of this research were discussed.

Chapter 4 : Research Findings

4.1 Introduction

The findings originate from 8 industries and arise from analysis of 35 interviews, observations and document reviews. Nineteen sites cover architecture, education, insurance, law consultation, management consultation, manufacturing, scientific services, and software services. As previously described, the case study data was analysed via thematic analysis with the aid of the ATLAS.ti™ software.

In this chapter, the findings are presented in accordance with the structure indicated by Figure 4.1. Motivated by the knowledge representations of different knowledge types, this research explores the fundamental scope of knowledge, tacit knowledge and knowledge sharing, to see both the industrial takeup of definitions (Finding 1) and the eventual takeup of knowledge representations (Finding 2). The findings consistently show that participants have differences in domain knowledge and these differences elicit different knowledge representations.

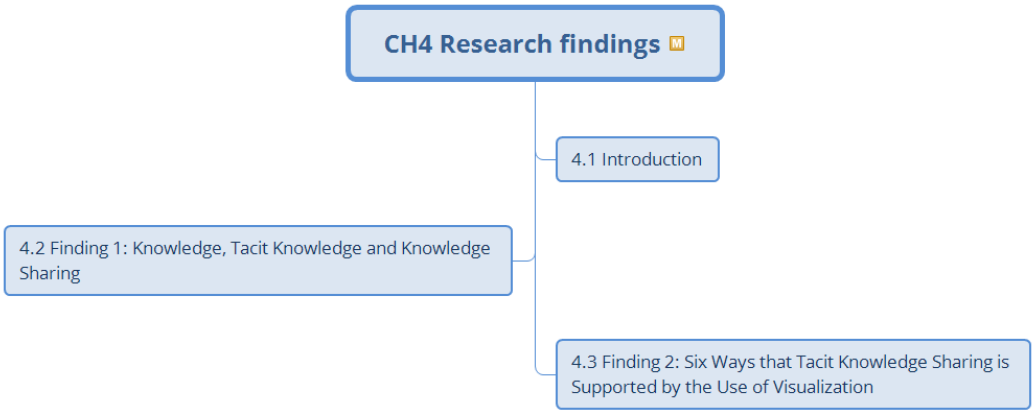

Figure 4.1: Research Findings Structure of Chapter 4

4.2 Finding 1: Knowledge, Tacit Knowledge, and Knowledge Sharing

The first set of major findings is concerned with how participants define and share knowledge and, in particular, TK. The approaches to, and misunderstanding of, knowledge is presented before evaluating three enablers of knowledge sharing.

Knowledge sharing differences are then derived via comparisons of industries and toolkits. TK sharing is considered in some detail.

This part of the findings is derived from document reviews, interviews and observations. Participants were interviewed about their perception of knowledge and their experience of knowledge and TK sharing. They were also asked about the differences between experts and novices. Their visual activities involving such media as publications and meetings were observed and reviewed to generate research themes and sub-themes. Table 4.1.summarises these findings.

Table 4.1: Themes and Sub-Themes: Finding 1

Finding 1: Knowledge, Tacit Knowledge and Knowledge Sharing	4.2.1 Approaches to and Misunderstandings of the Knowledge Definition	4.2.1.1 Three Approaches to the Definition of Knowledge.
		4.2.2.2 The Misunderstanding of Knowledge
	4.2.2 Enablers of Knowledge Sharing	4.2.2.1 Physical Proximity
		4.2.2.2 Motivation
		4.2.2.3 Domain Relevant Knowledge
	4.2.3 Knowledge Sharing Differences	4.2.3.1 Knowledge Sharing across Industries
		4.2.3.2 The Knowledge Sharing Toolkit
	4.2.4 Tacit Knowledge Sharing	4.2.4.1 Differences Between Experts and Novices
		4.2.4.2 The Tacit Knowledge Sharing Toolkit
		4.2.4.3 Achieving Tacit Knowledge Sharing

4.2.1 Approaches to and Misunderstandings of the Knowledge Definition

Although participants used one of three distinct approaches when defining knowledge, some participants had no idea how to define it and some overgeneralised it, reflecting a misunderstanding of knowledge.

4.2.1.1 Three Approaches to Defining Knowledge.

Participants tended to define knowledge using either an information-based approach, a mixture of objective facts and subjective perception, or an understanding-based approach:

Perception 1: Knowledge is Information or is Information Based

Participants often tried to use an information-based approach to define, interpret, and explain knowledge. Hence, knowledge is considered to be information (especially by the scientist participants). According to one respondent (coded as respondent A501, 46:2):

> "Knowledge is basically any information. To me knowledge is information." (A501, 46:2)

For other scientists, information was taken to mean the source of knowledge and hence can be converted into knowledge. One participant followed a Data-Information-Knowledge-Wisdom (DIKW) approach and interpreted knowledge as the evolution of information:

> "I would take it as using data and information, as what you do with it, how you interpret it, what you infer from it, turns those things into knowledge. So drawing conclusions from it, and references and that kind of thing. So, use data and information and turn into knowledge." (A306, 40:10)

For others, knowledge requires extra effort when it is added to its source. From the DIKW evolution of facts standpoint, information serves as the source of knowledge after it is connected and synthesised inside our brains:

> "Knowledge is about making sense of facts by streaming things together. So, I can make information connected and create a synthesis of ideas that is bigger than the individual Google docs.... knowledge isn't about me drawing a bunch of boxes here, and saying 'here're the facts, this, this, and this...', you know, it's about how we connect that information together." (A302, 9:1-2)

Two interesting points were noted. Firstly, although participants had no difficulty identifying information, some of them were puzzled when asked to identify knowledge. For example, one scientist participant viewed knowledge as information. Secondly, although some participants have difficulty defining

knowledge, they can still acquire it, use it, and share it with others. In short, unawareness of a definition does not seem to affect practical use.

To identify the relationship between knowledge and information, three criteria were considered by participants:

- *Information is the Source of Knowledge:*

One participant thought that information was a subset of knowledge sources, which is again coherent with the evolution of facts (DIKW) standpoint. To turn information into knowledge, individual effort needs to be involved based on experience with related people, events, activities, and circumstances:

> "One of the things that fits into building my knowledge is information. The other thing that fits into it is people. And another is events, activities and circumstances. All those things grow my boarder knowledge base. So, I think information, in my personal view, is a subset of what resources I draw from to build my knowledge base." (A1201, 63:2)

As the participant explained, his expertise grew when he assimilated all the incoming information.

- *Information is Outside of People While Knowledge is Inside People:*

One participant works as a legal mediator and uses his own specific expertise to resolve client conflicts. Because he needs to observe the participants and lead them to a collaborative discussion, his perception of knowledge is based on people. He thus treated knowledge and information as being inside or outside of people:

> "I guess information is what presents to me or what I present to other people. And knowledge is what I gain from that, what I gain from meeting on how we perceive the world." (A601, 52:2)

This viewpoint was supported by another comment that emphasised working with his personal knowledge base. He works with clients rather than machines or concepts, which is different from the scientist participant situation:

> "I think I have a good basic knowledge of the law because I'm a lawyer, but my focus is providing solutions. And my knowledge is very much about what makes people tick, people's motivations, how they understand the world, how they communicate that, and working with people to shift that understanding I think is my skill base, my knowledge base." (A601, 57:10)

- *Information is Recordable.*

From the perspective of being recordable or not, it is reported that if knowledge is expressed in either written form or verbal form, it becomes information:

> "I guess information and data are more easily recorded. You could almost argue that once you take knowledge that someone has, you write it down and it becomes information because it can be passed to other people more easily or something. They could argue that knowledge is tacit by definition; once you write it down you turn it into information. But it makes sense to me with such a clear definition." (A306, 40:11)

In summary, knowledge is perceived as having differences from information in the following ways: knowledge is made of information with people's effort and experience, knowledge is internal to people while information is external, and knowledge resides within individuals but if recorded it becomes information.

Perception 2: Knowledge is a Mixture of Objective Fact and Subjective Perception

Knowledge is perceived by some participants as a combination of objective facts and subjective perception. In this approach, knowledge is treated as the mixture of training, with formal knowledge provided, plus life experience:

> "Knowledge is a combination of symmetry of training from the university, and life experience. For example, (a technical person and an artistic person) they both have training, they both have knowledge from training in the university, but maybe a technical person lacks life experiences and is more controlled by parents, and maybe that's why he is technical. The knowledge that the technical person got is quite logical, one plus one plus one plus one... an artistic person has a free life, traveling and… at 20 years of age has more life experiences, so different ways of thinking, and different knowledge bases. So, knowledge is a combination of life experience and training." (A1801, 84:4)

In the eyes of the legal mediator, knowledge is a combination of facts and perceptions when he is very focused on individuals and trying to discover the facts and change opinions. Here, three parties were involved: the facilitator, the knowledge holder and the receiver. The facilitator provides an environment and guidance to lead to a rational exchange of ideas, while the knowledge holder tries to interpret and express what he knows. The issues which arise here are that people tend to interpret incoming information based on their prior knowledge or their filter

of knowledge; if the perspective is changed, people's perceptions will be different, thus a holistic perspective can be helpful for solving problems:

> "Knowledge is a mixture of fact and perception. One of the biggest things we do as mediators is to work out how people's perception is influencing their perspective. Often, we have people who come to a mediation, who would say that they KNOW they know, they said they KNEW what the answer was, they KNEW what the problem was, and failed to acknowledge that part of their knowledge is constructed by the perceptions. Every person in the room is given the chance to understand how everyone else views the world, and they can then move on to a position where they can see things slightly different." (A601, 56:1)

Perception 3: Knowledge is More than Understanding

The understanding-based approach considers the different ways in which participants understand or explain knowledge. Understanding is thought of as the process of building knowledge inside oneself. While explaining the knowledge sharing process of 'going from inside to outside' one participant noted:

> "I guess it's different levels of understanding, so you can have knowledge without having understanding. You can know about something, but still not understand it. While in science, we're trying to understand it, understand and then explain. So, knowledge is not something that I would sort of think of understanding or explaining as more of our roles." (A304, 20:2)

To explain the difference, the participant further clarified that explaining is an outwards process while understanding mainly happens inside the individual:

> "Explaining is passing on your understanding, transferring your understanding to another person. So, you may understand it, but then you must explain to someone else so that they may understand it. That's the idea of the scientific paper. It's explaining your understanding, the process." (A304, 20:3)

Visuals can facilitate explanation by articulating the imagination onto a piece of paper, thus making the knowledge understandable for the recipients:

> "I guess you could say I have it, but I consider it a tool, a technique to help visualisation, to explain, I know how this thing looks in my head, but to explain it to you…I wish you could read my mind, so to explain to you the basic concept, I have to do a sketch." (A802, 71:40)

Moreover, successful sharing of knowledge depends on both two parties: the knowledge senders and receivers. The owners of knowledge may understand what

they know, but they may not know how to share that with others. The capability of the receivers is also critical for this process:

> "You could understand how a person thinks but, for example, you might not understand the technical side because you're not technique trained. Probably you would need to explain how you are thinking, or you may say...'I don't understand that.' That's really hard for someone to say." (A1801, 91:22)

Some contradictions were found from this research related to this approach. For instance, with speaking skills the learners can observe how others speak and then mimic them without understanding the reasons or the importance of the actions. In other words, learners can be aware of and practise skills, and can act the same as an expert while they still have no ideas why the expert behaved in that way.

This lack of understanding seems not to hinder the action – the tacit skill acquisition. As was observed one day in speaking club B1, many advanced speakers did not express the words 'Thank you' to end their speeches. One of the advanced speakers even stated that they did not use "Thank you" to end their speeches. But some novice speakers did not understand why and expressed puzzlement during their evaluation. Although the novice speakers did not understand, they mimicked the action of showing their hands to the host to indicate the end of their speech.

From this approach, participants took knowledge to be of three types or levels: knowledge that an individual does not understand; knowledge that an individual understands; and knowledge that an individual understands and is able to explain. And, as was reported by the participants, while lack of understanding seems not to affect the exploitation of knowledge it does affect the sharing of knowledge.

4.2.2.2 The Misunderstanding of Knowledge

Several confusions were detected around the basic understanding of what knowledge represents:

Participants do not Use the Word "Knowledge"

Most of the participants would pause a while to think about their definition of knowledge when they were asked to provide one. Some stated that they have never even thought about a knowledge definition. One participant (researcher) thought

that the reason for this difficulty is that knowledge is a difficult concept for researchers, let alone ordinary people:

> "In my belief, it's very difficult for people to understand the concept. Talking about the definition of knowledge, Plato defined knowledge as Justified True Beliefs...There is a lot of crisis in modern technical and philosophical circles about that, particularly in the knowledge management circles because many people in my experience equate all knowledge with fact. The trouble is, with tacit knowledge, you can believe something to be true and act as it is because that's what you know and yet be at fault. You must understand the knowledge. The other thing people sometime feel confused about is information, the reason for that is because the DIKW hierarchy is thoroughly misunderstood." (A101, 4:8)

'Knowledge' is Used Interchangeably with Other Terms

Participants often confused the definition of knowledge and expressed such terms as ideas, facts, and information interchangeably. When providing a definition of knowledge, **the term *ideas* and *facts* were used as synonyms of information**. One participant talked about his definition of knowledge and related knowledge to ideas, then differentiated knowledge from facts, and went onto describing the relationships between them:

> "I think knowledge is about... the connection between ideas, that make ideas have value, so knowledge isn't just about facts, facts are important, but you can have plenty of non-factual information that came to apply in terms of generating an understanding of how something works, or how would I change. So, I think knowledge is a resource that I will tap into for helping with problem solving, I think it's a level of understanding which has almost cultural significant status, maybe not NZ society, but internationally. But I think that the important element again is the connections between things. So, knowledge isn't about me drawing a bunch of boxes here, and saying 'Here're the facts, this, this, and this...', you know, it's about how we connect that information together." (A302, 17:17)

Due to its vague nature, **knowledge sometimes is considered equal to information, or to a broader concept that includes information as the subset**. This misunderstanding can result in further confusion or to an overgeneralisation on knowledge:

> "Knowledge is really broad, it is basically any information, to me knowledge is information. We have fundamental knowledge, (and) apply knowledge to a certain area. Knowledge to me is a catchy word.

> So, you have knowledge about how to do something, you have knowledge about software you have developed, you don't have knowledge until you use that knowledge. As a research organisation we have a lot of people who have knowledge on science areas, we have plants and technology, engineering technology, software, physics skills; that's all knowledge." (A501, 36:1)

One participant stated that knowledge can be used to differentiate people and is an attribute of people. This enables people to differentiate themselves into groups that emphasise the importance of people as knowledge holders:

> "It makes people different to each other on a certain level." (A303, 18:18)

Effective KM encourages people to learn more easily and share more effectively in a business setting. Moreover, because people are the holders and carriers, KM is about managing people with knowledge rather than managing knowledge itself. This implies that, to exploit knowledge, an appropriate environment and tools must be provided for people to help them learn and communicate easily. One participant, explained his organisation's perspective:

> "We are trying to change people's behaviour, get them collaborating, working together and communicating, so that a key part of our strategy is about to providing people with ways to behave differently and work together. So that's what we've been focusing on in Information Management: developing the infrastructure and giving people the collaboration tools and communication tools. So, I guess in that way, we've been trying to create a knowledge management approach or knowledge management environment. We try to provide people with ways to share knowledge." (A306, 40:1)

This statement shows that information infrastructure only provides an environment to facilitate the exploitation of KM. Individuals in the organisation who make use of the facilities are the real power behind KM.

Knowledge is Generalised to Everything

Another apparent confusion around the knowledge definition is that **knowledge is over-generalised and broadened to extreme levels.** One participant, who was trying to clarify his understanding of knowledge, first tried to explain his expertise as being a subset of knowledge, and then his expertise in other fields as something more than his expertise. but which could still can be treated as knowledge. He

declared he had "a broader definition of knowledge", although it seemed he cannot explain what this is. In response to the researcher's explanation of skill and expertise, he stated:

> "That's your interpretation of skill and expertise. That's one way you can define knowledge but I think knowledge has a lot more. My knowledge, overall, is constrained to my area of expertise. I'm a chartered accountant in this firm, so I've got a certain set of skills, you know expertise around accounting standards, around provision and providing financial information, financial analysis, and that's my specialised area, that's my expertise. But it doesn't represent the knowledge that I have. I also have knowledge in terms of the profession. But I have a wider base of knowledge about the market, and about the people that I work with. I have a boarder definition of knowledge." (A1201, 70:1)

Again, this confusion seems to have its origins in the vague nature of knowledge.

4.2.2 Enablers of Knowledge Sharing

Three enablers of knowledge sharing were detected in this research. All the research data was sourced from interviews, observation and document reviews. No direct questions were asked during the interviews; rather the themes emerged during the data analysis process:

4.2.2.1 Conveniency

The first enabler is **conveniency**, meaning that there is little in the way of a physical barrier to prevent knowledge workers from communicating with each other whenever they choose. Several types of techniques to improve conveniency are identified: open offices, whiteboards/pin boards, open meeting rooms and availability of facilities

Open Offices

Several architects were observed to be working in a large and open office, with all their computers positioned back to back on a single large table. In this way, the architects can sit and face each other:

> "We all sit in an open plan office and we don't have individual offices. We work together on all the projects, so that's kind of what I mean by collaboration." (A1701, 93:8)

Open space in the working environment is believed to be encouraging in terms of collaboration and knowledge sharing:

> "I guess part of the reason for us having an arrangement like this is so knowledge moves between us quickly, like no barriers. I think that's something we've seen since we moved here from another office nearby. We are a little organisation that wants to break down barriers between the staff and create spaces where people can collaborate and talk and share ideas." (A1701, 94:6)

The collaborative configuration of the working space, Figure 4.2, makes individual learning able to contribute to group learning. In other words, the open office encourages the sharing of knowledge in real time and between every team member:

> "Because all of us work on several projects and you pick up stuff all along the way, it's possible to think about how that captured knowledge can be shared within the team. Everyone can learn rather than just one person learning something." (A1701, 94:15)

Figure 4.2: An architect's Open Plan Office Space

Source: Photo credited to the participant's website

One wall of the office is used as a whiteboard, so that anytime someone wishes to discuss something, they can draw and elaborate the discussion, Figure 4.3.

Figure 4.3: Open Layouts Enable Real-Time Knowledge Sharing

Source: Photo credited to the participant's website

These layout features can be explained by the nature of the job the architects are doing. Their clients come to them, tell them what they like, and ask them to provide some options for a new building. Although the architects have the client's input, rarely is it completely clear or complete. This makes it vital to clarify the client's wishes with the aid of verbal and graphical communication:

> "As the clients are telling us what they want, we put that into our own words and use graphics to show how we have interpreted what is being said. We also check our understanding as we need to be careful when interpreting initial ideas. Are we picking up on the subtle hints and understanding what they want?" (A1801, 92:23)

After the initial client discussion, the architects draw a sketch or create a 3-D computer model, depending on the client's request and level of interest. Although instigated by the client's need, the architects themselves need to be creative and generate some reasonable options. Really complicated projects require the architects to discuss more often to get ideas from the group:

An open space layout is not always a good thing since it can raise confidentiality and privacy issues:

> "The downside of this open plan office layout is that, when clients come here we don't want them to see someone else's project. That's why we installed a curtain that we can place in front of the whole board." (A1701, 84:4)

Whiteboards and Pin boards

For the scientist participants, an idealised working day involves leaving their own office to collect data, returning to their office to analyse the data, discussing findings with peers during break times, and writing articles for conferences and publications. Because they spend most time in their office they need a private workplace in which to devote time to analysing, thinking and writing. For these reasons, scientists were all found to have a private office which, although not large, contains a whiteboard and/or a pin board, Figure 4.4.

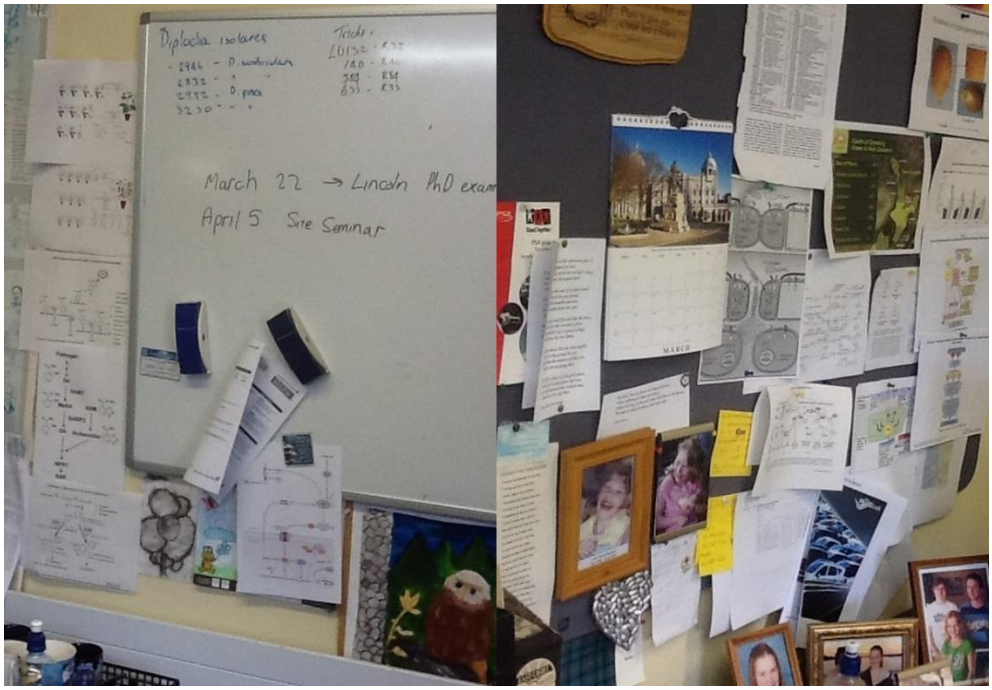

Figure 4.4: Scientist's Closed Office with a Whiteboard and Pin board

Source: Participant (A503, 50:2)

Scientists mainly share their knowledge, whether in explicit or tacit form, via discussions, or while at conferences or in written publication format. They also need to spend time converting their TK into its explicit counterpart. Moreover, as every scientist has expertise in a specific domain and scientific advances tend to be incremental, there is not so much need to collaborate and contribute fresh ideas in group settings.

Meeting Rooms

A meeting room complete with a whiteboard was observed to be the norm in several of the case organisations, including the law consultant organisation and the engineering organisation. The law consultant had a glass whiteboard in the meeting room on which everyone could draw and refer to it, Figure 4.5

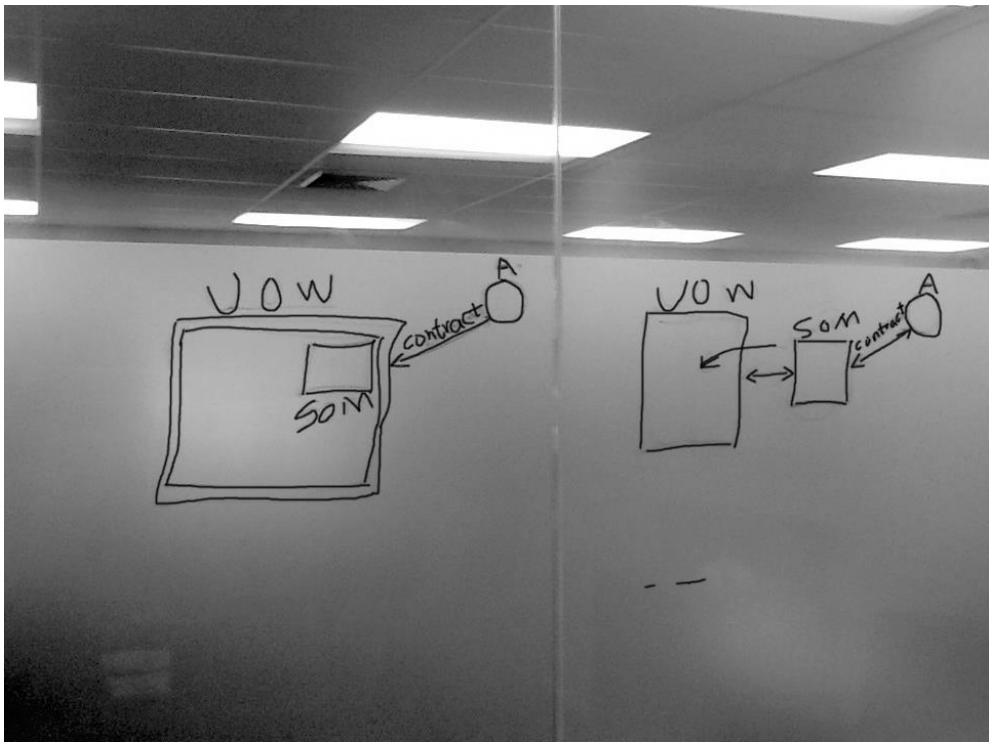

Figure 4.5: Utilisation of Visuals

Source: Participant (A701, 61:1)

Figure 4.5 reveals that some users can employ visualisation tools tacitly. This participant chose squares to represent the organisations and a circle to represent a person. He used assorted colours, locations and sizes to show the different organisations. A dual-ended arrow was used to show the contract between the person and the organisation. During his illustration, he used his marker to point to the key content he was articulating, and showed the movement of his marker for the interaction between the organisation and the person. The colours, locations, sizes and movements indicate his perception of the relationships between the subjects without any articulation beforehand. For the listeners, it is natural and easy to grasp what the sender is trying to show. The tacit part of the sender's knowledge—the relationships between the organisations and the person--was transformed into a drawing and then passed to the receivers quite successfully in this way.

The previous findings were echoed by an in-depth case observation. A manufacturing company, coded as organisation A8, converted all the walls in two meeting rooms into whiteboards, and used these for an upgrade project. One of the meeting rooms was named the 'War Office'. Through the doors the whiteboards and sticky notes on the whiteboards can be observed, Figure 4.6.

Figure 4.6: War Office in one Organisation

Source: Participant (A801, 65:3)

All the people involved with the same meeting or discussion could contribute to same project, Figure 4.7. It was thought that this would provide a neutral place for people to discuss and collaborate, which contrasted with the regular workplace and outside culture:

> "Yeah. We opened those rooms up at the very start of the project. We converted those because we knew we would need a space to do our work together that was, you know neutral, and out of everybody's normal territorial zones and everybody's offices. No, it wasn't the managers' office, or the board room, it was just these two rooms that we just dedicated for the purpose. That's all that we've used them for." (A802, 71:16)

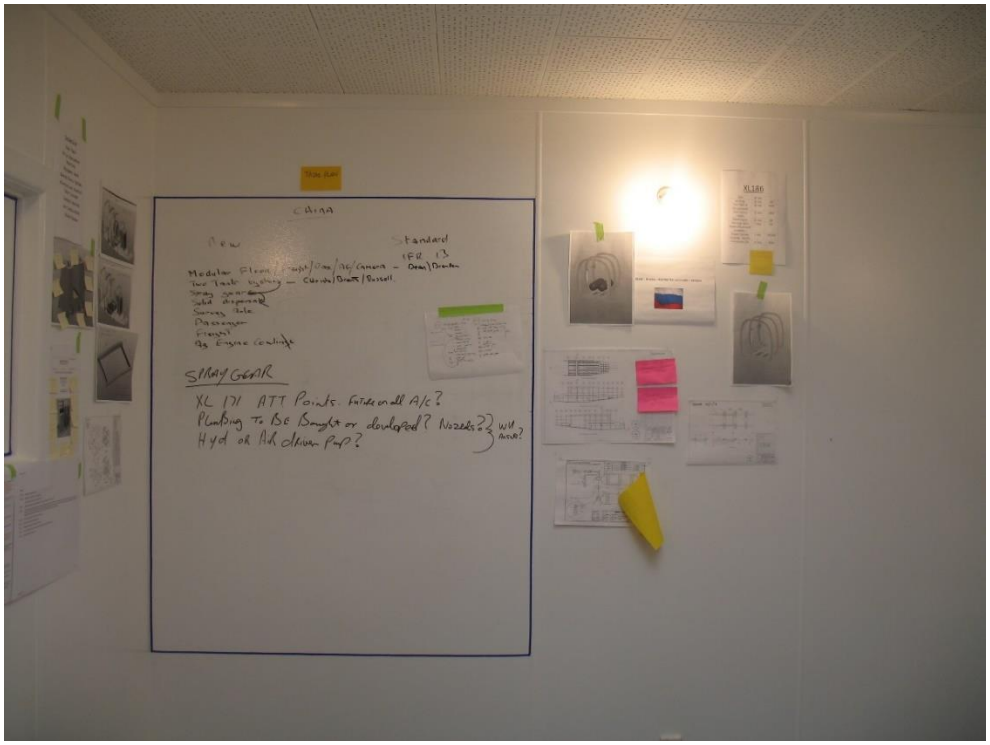

Figure 4.7: Meeting Room Provides an Open Space for Participants

Source: Participant (A801, 65:4)

The rooms were thought to contribute greatly to the projects, but eventually their use was terminated. The culture proved hard to change and everything resumed its previous state:

> "Yeah, the boards were perfect for that part of the project, which was a great decision from the CEO. I guess he knew that we needed a facility to manage ourselves, to meet the demands of the project. But then because of the old culture, they don't get used so much anymore." (A802, 71:3)

Whiteboards were kept in use in individual offices to access and develop ideas. As was reported by one participant:

> "My whiteboards are always full. Some of the ideas stay there for a long time until the project is completed, and a lot of ideas I sketch up there, so while I'm working I look at them, and just looking at them my mind will work on them which is normal. You start to figure out better ways or changing some part of the idea, you know." (A802, 71:18)

Another point was observed during the interview with participant A802, who used the drawing technique so adeptly that when he was interviewed he drew another version for the researcher. The drawing made his narration much easier to follow as he kept talking about so many details. As the discussion continued, the sketch

was drawn in accordance with the pace of the discussion which clarified the verbal counterpart and emphasised the key points.

Availability of Facilities

In addition to meeting rooms, the availability of communication facilities such as Skype is the fourth knowledge sharing enabler. From the viewpoint of one participant, ease of finding facilities in which to discuss ideas with colleagues can encourage people to talk more and thus facilitate knowledge sharing. People no longer need to travel to see each other and can set up a virtual meeting with colleagues from around the world. An online chat platform such as Skype makes remote discussion with similar minds very convenient:

> "We have four video conference facilities in this building. I guess the reason we first got them is to try to cut down on travel expenses. It has done that, but I think it has also led to more meetings, in fact shorter meetings. These are better managed because you can only book for up to an hour. So that brings efficiency, saves money and time management is better. You communicate more. Soon a new system will let us Skype directly from our computers to everyone else over a high-speed network, which should be even better." (A303, 18:17)

As noted by another participant, the availability of communication tools is the basic approach to managing knowledge in the organisation:

> "We are trying to change people's behaviour, getting them to collaborate and communicate more, so we are about to provide staff with new ways to behave differently and work together. So that's what our information management has been focusing on. Infrastructure development will provide people with the collaborating tools and communication tools so I guess in that way we've been trying to provide a knowledge management environment and getting people to work in it without really writing it down as a strategy. That's what we call KM." (A306, 40:1)

Open space gains a popularity over the other factors for many reasons. First open space is where participants come to talk, share and motivate each other. It enables the interactions between people. Second it is an economical way to encourage more sharing between participants. Other than the soft characteristic of the other enablers, open office, whiteboard or a meeting room is easy to set up and motivate conversations between people. Lastly, open space is easy to be reminded by the

participants and spotted by the researcher thus takes several pages in this report. But this does not reduce the importance of the other factors.

4.2.2.2 Motivation

The second enabler is motivation, aiming at the factors motivating the knowledge holders to share their knowledge. Appropriate expression and willingness have been noticed.

Appropriate Expression

The appropriate expression of knowledge sharing concerns interpersonal relationships. Appropriate expression of the issues can accelerate knowledge sharing between different people. For example, each scientist has their own field where they treat themselves, and often are treated by others, as experts. When the others want to discuss topics with them, an appropriate expression of the issues can make people be willing to open up and discuss the topics with an elevated level of engagement. Persuading colleagues to listen and look at things from an unfamiliar perspective can be hard to achieve. In the view of one scientist participant:

> "People are often overworked and stressed out by their work, so if I come to them with a new problem, their first response is 'Go away, I haven't got enough to do, right?' The next response is 'You're insulting me because I'm doing my job really well, so don't tell me I'm not'. That's what they think, right? So, there's always an interpersonal relationship that you need to bridge. Maybe you could say something like, 'Think about whether there might be some opportunities here for you to do your job in a different way. It may cost you more, it may cost less. But just let's think about it'. You know, that kind of thing." (A302, 11:11)

Similarly, in the speaking clubs when an evaluator was asked to provide feedback to a speech, the official guide book recommends that evaluators should organise the evaluation in a way that is both encouraging and motivating.

Willingness to share

It was observed that willingness to share and to learn from opposing views can facilitate the knowledge sharing process. One participant valued individual willingness as being critical to knowledge sharing in an organisation:

> "Behind discipline it's just willpower. That's the driver, the willingness. So that's the seed and everything else grows from that. If your level of willingness as very high there's a very good chance that you will achieve what you want to achieve." (A802, 71:64)

A (learner) participant asserted:

> "The link between willingness and visualisation is that you have to accept that you CAN do that and you have same capacity to do that as everyone else. Then comes practising and developing that capacity, you have to work on that." (A802, 71:65)

The learner's willingness can lead to full involvement with outside representations such as drawings then make TK exploitation possible. The interaction between inner visualisation and drawing developed the participant's concept building process and his TK exploitation process:

> "Sometimes if I visualise a problem and it doesn't quite lead to a solution, I'll do a sketch to work out a better visualisation. While I'm visualising I will be sketching because solutions you develop have to start somewhere. I will develop them out of nothing to come up with a variety of action solutions. Sometimes that's a multi-stage process." (A802, 71:30)

4.2.2.3 Domain Relevant Knowledge

Domain relevant knowledge is reported to be a facilitator to understanding the incoming information, whether it be from a visual source or a verbal one.

> "If you put this in front of someone who doesn't really know a lot about business it might not make a lot sense to them." (A1201, 73:4)

Domain relevant knowledge makes it easier to understand a specific domain, or attracts one to a relevant field:

> "If you are reading this paper, it kind of assumes you have some knowledge of molecular biology to be able to understand it. If you were in that field before, you will pick it up [easily]." (A401, 42:2)

To summarise, the three enablers of knowledge sharing in the organisations studied were reported to be: conveniency, motivation, and domain relevant knowledge. It seems that the internal factors, motivation and domain relevant knowledge, play more important roles than the (easily substituted) external one, conveniency which

includes open offices, whiteboards and pin boards, meeting rooms, and availability of facilities.

4.2.3 Knowledge Sharing Differences

4.2.3.1 Knowledge Sharing across Industries

This research focuses on the analysis of the scientist and architect data samples to compare industry traits. The skill of the laboratory technician and the scientist tends to involve exploring the outside world and explaining the findings in the form of text, equations, and theory. Their knowledge tends to be objective. In contrast, management consultants, manufacturers, and architects work in a more artistic way that blends their skills and intuition. They work on problems with clients and must discuss with their colleagues the best solution for that situation. Their knowledge tends to be subjective.

Knowledge Shared by Architects Tends to be Tacit

The definition of knowledge held by architects is very different to that of scientists. One architect participant commented:

> "You can't quantify the creativity in a building. Unlike science and engineering [outputs], which you can quantify, our industry is subjective. Our industry is us!" (A1801, 97:28)

Architects believe that knowledge combines life experience and training, so knowledge can be obtained from real work experience. The tacit part of knowledge, rather than the explicit part, is emphasised by those working in this industry who treat knowledge more as experience and perception. The representations they choose to illustrate their knowledge are also distinctive and the language mainly involves graphics:

> "In terms of communication, most of our jobs are done on computers these days. That means we can produce line drawings and all kinds of graphics, right through to photo-realistic stuff in Photoshop. We also create physical models. We build things these things to create and communicate our design ideas." (A1701, 2:2)

On the other hand, because the knowledge that architects hold 'is artistic' and can only be developed with life experience, it is hard to share:

> "It's very hard to share life experience. It's an art form. You can't document it. It's not science so you can't be like an engineer or scientist and document it, put it in a file and say, 'Learn that'. (A1801, 91:18)

When the question was raised of whether it might be possible to use cases and stories to share such knowledge, the response was:

> "Yes, you could case story a project in a recorded file, and say 'Learn that'. This would need a hard knowledge base script in a file and the other half would be learning from life experience." (A1801, 91:18)

Architects begin a new assignment by trying to define client needs, then brainstorming viable solutions, before narrowing down to one or two solutions, then working on a preferred solution. Their thinking style goes from divergent to convergent, which sometimes includes many divergent-convergent thinking phases within the cycle. Even the architecture industry, which is considered to be artistic and intuition based, has its technical side:

> "We've got two graduates in the company. One is a technical person; very practical with good analysing abilities. The other is an artistic person. That's the nature of how they grew up as children, how they think. Both have experience and an architect's degree, but they do things differently. The technical person can't do the artistic one's work, the artistic person can't do the technical person's work. That's fine. When we have a technical problem, or technical project, we use the technical person. For artistic projects we use the other one." (A1801, 91:12)

Knowledge Shared by Scientists Tends to be Logical and Explicit

Knowledge sharing is quite different in the science industry where participants always try to document their knowledge into files, and share them with others. More than the architects, scientists related more with information. As one scientist stated:

> "Knowledge is really broad, knowledge is basically any information, and to me knowledge *is* information. We have fundamental knowledge, and apply knowledge to a certain area. Knowledge to me is a catchy word. So, you have knowledge about how to, you have knowledge about software you have developed, you don't have knowledge until you use that knowledge, differentiate people and differentiate wrongs…as a research organisation we have a lot of people who have knowledge on science areas, plants and…, engineering technology, software, physics skills that's all knowledge." (A501, 46:1)

For scientists, the definition of knowledge tends to follow the approach of information evolution, so they often use information to define knowledge. One participant said:

> "To me, it's [knowledge] sort of useful information that surrounds us in varied forms…you know, varied forms mediums that you can basically use to do your job or get into your life." (A303, 18:1)

Scientists often start with questions/hypotheses and use a set of measurements to find answers. The overall thinking style behind this process is convergent rather than divergent:

> "You have a hypothesis saying how you think something functions, and you test your hypothesis by doing experiments. If your experiment supports your hypothesis, you are closer to understanding, like a system. So, for me knowledge is actually being able to explain how something works." (A504, 53:10)

So, the result of the scientific approach is that knowledge is more theoretical:

> "Yeah, academics build on knowledge to develop theoretical new conscious ideas. Knowledge can be very narrow and very structured so it may not cover lots of human situations. So, you can do something academically and theoretically, but to relate it and to use it, that may not cover all aspects." (A501, 46:3)

The thinking style of scientists is logical and process driven:

> "Well I don't actually know if there is just one way. I think it's about things working in combination and the process is important to me because I'm a process thinking scientist. You know, some scientists are more structured thinking whereas I tend to think about what things do and how they work. Some scientists would say 'Show me a few pictures of fish swimming, that's all I need to know.' But for me I want to know what these fish do; you know, where they live, what they eat, those kinds of things. So, the process to me is very important. But also, the diversity. the structures are important, the connections between the animals and the chemistry and physics are important. I think all of that is part of the story, so I don't think one element is really critical." (A302, 12:16)

When comparing the architects with the scientists, several differences were noted:

1. The nature of the industries is different which leads to different choices. Architects interpret client needs and develop ideas into reality for a building to meet client specification. This reality is based on interpreting architects' and

clients' ideas. On the other hand, scientists often start with a hypothesis and then employ experiments to support them.

2. Their respective needs to share knowledge are different, which leads to different mechanisms for knowledge sharing. The architects need to contribute to the same project synchronously and were observed to use an open plan office space to fulfil this demand. Scientists mainly share their knowledge via peer-reviewed papers, so they need to conduct individual work before sharing it with others.
3. The thinking styles during the knowledge sharing process are different. Architects use divergent thinking first and then complete the project with convergent thinking, while scientists tend to use convergent thinking throughout.

To summarise, different industries share knowledge differently, as is demonstrated by architects who mostly try to share their knowledge via experience, whereas scientists mostly use publications. These differences are partly due to the different knowledge sharing demands in each industry.

4.2.3.2 The Knowledge Sharing Toolkit

Little research has focused on individual knowledge sharing implementation and its tools. In this present study, participants were found to use multiple representations to communicate: verbal language, body language, visual language and written language. Figure 4.8 indicates the knowledge sharing channels and activities involving two individuals.

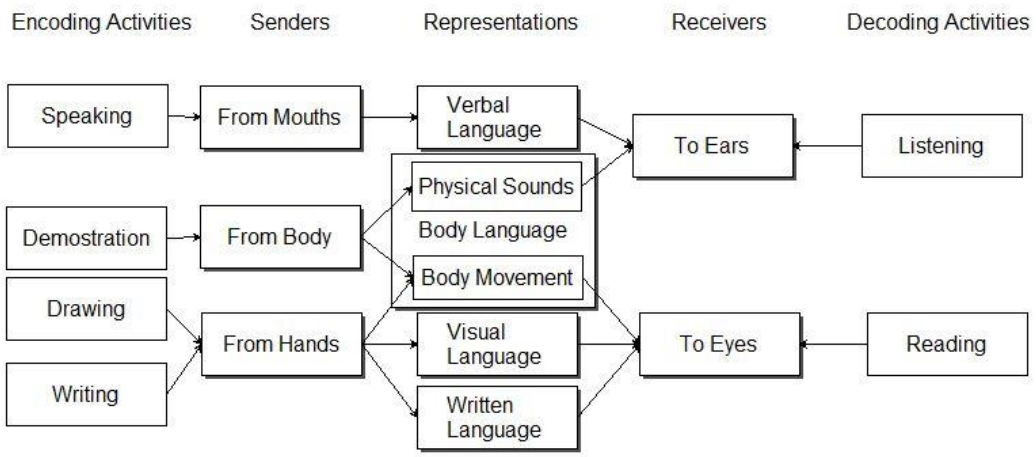

Figure 4.8: Communication Toolkits detected by this Research

On the sender side, the encoding activities of speaking, demonstration, drawing, and writing variously involve the mouth, body, and hands. Thus, the representations that can be employed are: verbal language (transmitted from mouth to ear); 'body language' in the form of physical sounds (from body to ear) and body movement (from body to eyes); visual language (from hands to eyes), and written language (also from hands to eyes). On the receiver's side, the decoding activities involve listening and reading (the situation) using ears and eyes These relationships are now elaborated upon with reference to the research data.

Verbal Language

Verbal language seems to be the most popular and convenient for participants to use in terms of communication. An accountant reports how he generally interacts:

> "We talk about the way we will go about looking at documents, contracts, or invoices, or whatever the support may be…to make sure that we're happy the numbers in the financial statements are correct. We discuss for example how to pass that knowledge on. We have conversational briefings with staff members as they are going through and doing the work. We give them coaching around what they need to do." (A1201, 73:17)

Some participants are good at verbal communication and rely on this rather than use visual communication channels. In this regard, speed and convenience are important considerations:

> "I can talk pretty fast, so I can communicate a lot of ideas in words quite quickly when describing what I'm thinking. If I have to draw a diagram on a computer it takes forever to do a good graphic. I can draw a whiteboard very quickly too, so if I could draw a live diagram and cut it out to make it pretty that would be great. But it is frustrating that I can't do that with PowerPoint." (A306, 40:15)

Even when using the same presentation media, different people achieve different outcomes; it depends on the skill level:

> "I think you need to keep it very simple. Some people are not actually good speakers; you can get two people doing the same presentation, one would make it fun and interesting, while another bad speaker can't do that." (A504, 53:3)

Sometimes verbal communication is chosen because of audience preference. The architect participants will use different language terms (general or technical), depending on the audience they are facing:

> "Our industry is all about trying to sell ideas. Some people can understand technical ideas that are presented verbally or in a script… such as when we report to boards, trustees, and founders. With user groups, a lot can be lost in translation. If you explain to them verbally and put that in a script, they can misunderstand what you're saying. You have to explain to them first, and they have to understand what you're trying to say". (A1801, 97:9)

For the receiving party, the decoding process related to verbal communication involves listening. Successful decoding of an incoming message has certain requirements, including background knowledge and clarification skills. One participant referred to this as 'life experience':

> "When our clients say what they want we express that [back to them] in our own words. Our graphics also show how we have interpreted what the client is wanting and if we understand what was said. 'Is this what you want?' We need to be careful when interpreting initial ideas, are we picking up on their hints and understanding what they want? It's really life experiences." (A1801, 97:23)

Physical Sounds

As part of body language, physical sounds, such as are made by other parts of the body than the mouth, include clapping, stomping and finger snapping. A speaking club member was frequently observed to integrate physical sounds into her speech, which she believed was the approach to enhance her speech delivery. When she made a speech on Maori culture, she demonstrated to the audience how to do a Maori dance with clapping and stamping. It was clear that this passed messages which would be very difficult to convey through a verbal counterpart. In this regard, physical sounds would appear to be especially useful for TK sharing.

Body Movement

Also as a part of body language, body movement was observed to be one of the most important facilitators of communication. In the speaking clubs, specific speech projects are designed to practice those skills that improve performance in public speaking. These projects include using appropriate body language. An

appropriate stance indicates confidence and comfort level, as does movement from one place to another. Gestures from head, shoulders, arms, hands and so on, plus facial expression consistent with feeling or information, and eye contact all help to establish a bond with the audience. Practice is essential and a mirror is a device for incorporating better body movement:

> "The first time you incorporate movement into a speech it can be quite uncomfortable, but after some practise you're like, 'I'm doing it better now'. Yes, in front of a mirror, I can see exactly what I am doing. It's just getting that right." (B101, 234:16)

Similar to using sounds, body movement appears to be especially useful for TK sharing.

Visual Language

A comprehensive description of the visual language findings is provided in Section 4.3 which is concerned with visual representations.

Written Language

Written language as observed in this research predominantly appears in the form of books, presentations, manuals, reports, and journal articles. Written language is used either as a dominant language, in an article for example, or as a tool to complement other communication method. In a presentation, images and verbal and written communications often combine for an effective outcome:

> "I will use pictures and words to emphasise what I'm talking about. You might put one or two pictures up that people can all look at, and you can talk to that. That captures their attention." (A1201, 73:7)

4.2.4 Tacit Knowledge Sharing

According to Nonaka et al. (2000), unlike EK which has an objective nature and can be expressed and shared in tangible form TK has a subjective nature and is highly personal and hard to formalise and share. However, by examining the knowledge sharing process on the sender side and the knowledge building process on the receiver side, a conclusion that TK is shareable is reached.

4.2.4.1 Differences Between Experts and Novices

The interviews and observations reveal differences between the knowledge that is possessed by novices and experts. As mentioned earlier in Chapter 3, the participants were not labelled as a novice or an expert until they were engaged with a specific topic during the research. Also, it is noted that every participant can be an expert in a specific area while also being a novice in other areas at the same time. Novices predominantly know the 'what knowledge': the factual or conceptual and fundamental kinds of knowledge. Experts, in addition, know more about how to do things. This difference appears to be due to life experience—people who dwell for long enough time in a domain can pick up knowledge from their experiences:

> "I know I am different to the novices. We probably have some common knowledge, but in the areas I specialise in I know that I am probably better than them. Novices might know some of the fundamental things, but I know a lot more detail. It may be that I have wider experience because I have been working in this area longer than them, so I have picked up more knowledge." (A303, 18:3)

These differences can create advantages over those who lack knowledge:

> "The advantage I have over a novice is my [extra] experience in the situations I've been in. This affects the choices I make and how I actually view a problem." (A802, 68:4)

While it might be natural to want to help novices grow as quickly as possible, this wish seems no more than just a dream:

> "They need to grow up at their own pace. You cannot force them to grow fast." (A1801, 91:17)

This participant thought the leap from novice to expert needs "a few years' time":

> "She's been doing [task] for a while and her job involves lots of public speaking. So even just through practice she will be better than me at speaking. She does many tasks so she's just more skilled in general, I mean, she's sort of the way we want to be in a few years' time." (B101, 234:9)

Novices can know what needs to be achieved before acquiring that ability. In other words, they can judge the level of a skill before they own the skill. The speaking club evaluators routinely identify what has not been achieved during a speech even though they sometimes have not attained that skill level themselves. In this sense,

it is helpful to be aware of the advanced skills that require more engagement in order to be mastered.

4.2.4.2 The Tacit Knowledge Sharing Toolkit

Multiple means of facilitating TK sharing were noted from the interviews and observations:

A Healthy Culture Encourages Tacit Knowledge Sharing

Organisational culture was observed to be a critical factor that facilitates or hinders the sharing of TK, and knowledge in general. While culture is hard to express explicitly, it can shape the behaviour of individuals. In the words of one participant:

> "In that sense, culture is a tacit thing. How you interact could be the skill with which you operate within a cultural environment, a tacit skill." (A101, 2:1)

It seems that organisational culture is TK at the organisational level which, despite people not being fully aware of, they can recognise the signs of for themselves:

> "If you go into any workplace you can look for certain signs and symbols and the stories they portray. What pictures do you see? What monographs are on the walls? If the floors are dirty you know there is a good chance the culture there is different from a workplace that has clean floors, and so on. In short, these aspects, which are quite concrete, are expressive of culture." (A101, 4:9)

Such forms of TK sharing help build the context and relate the receivers' experience to the real situation.

Sharing Tacit Knowledge Requires Multiple Channels

To tell a story, every element of process, structure, and connection should work together. No single element is thought to be the most critical since they all contribute to the outcome:

> "Well, I don't actually know that there is only one critical piece of the puzzle, I think it's all of these things working in combination and the process is important to me because I'm a process thinking scientist so I don't think one element is really [critical]." (A302, 11:16)

Face-to-face communication is very important for TK sharing. However, when two organisations are located far apart they will need an alternative such as a video

conferencing system to encourage conversations between colleagues, and overcome the expense and time associated with travel.

Leaps of Faith Facilitate Tacit Knowledge Sharing

When TK cannot be communicated, the architect participants sometimes ask their clients to simply believe them and wait for the outcome:

> "That's what we call a 'leap of faith' or a 'jump of faith'. At the end of the day if you don't understand it, just trust me because this is how we do things, and trust me because when you get into the building, then you will think 'Now I understand it'." (A1801, 91:11)

A leap of faith, in other terms, is to *trust* one's expertise and intuition without any doubt. When TK cannot be articulated, trust can pave the way for the parties to remain involved.

4.2.4.3 Achieving Tacit Knowledge Sharing

Based on the interviews and observations it is clear that TK can be achieved via practice and learning.

Practice is Perceived to Make Perfect

Practice serves as the main means to gain knowledge and TK. One participant, who gained her public speaking TK skills by practicing in a club, emphasised how experience and practise helped her:

> "Certainly, nervousness is pretty common to everybody usually, and it's just the repeated experiences of getting up and speaking to a group of people that helps to overcome that." (B103, 100:2)

Awareness is perceived to be important for further TK building. When having an evaluation, one participant realised the difference between him and the advanced speakers, and tried to reduce the gap by mimicking the experts:

> "Yeah, they [the evaluations] are probably the second important part. The first is self-evaluation, when you're up there to speak you're probably aware of what's going on, what you can do better immediately, I think you're not going to apply it immediately of course you should focus on the speech, but next part you will think 'that's the language right? 'coz it's that person's perspective, right?' You know, for example,

> how my speech started quite strong, and then I just stopped it. I mean, there was not much they could evaluate on that. But you know, when you're listening to other peoples' evaluations you may think, 'Wow, maybe I'm going to do that as well.' …The key thing is you're aware that when you speak next time, you're thinking 'I'm not going to do that." (B101, 90:1)

To be aware of and identify the skills that need to be learned from others the participants used the knowledge stock in their own mind, which came from manuals or observation/experience, and this facilitated the awareness and recognition process.

The differences between a layman and an expert provide further evidence of the necessity of the 'dance' that takes place between perception, recognition, action and knowledge. When a layman who had only been with the club a few months evaluated an advanced speaker, the layman could not identify anything which did not go well and could not recommend improvements. On the other hand, someone who had been with the club for over a year noticed that the advanced speaker did not use her visual aids well and the content of the speech was not appealing to people, furthermore, the body language was over exaggerated and affected the efficiency of communicating the main ideas.

TK was perceived to accumulate with life experience that takes time, a perspective that is congruent with an approach which embraces knowledge as the mixture of objective facts and subjective perception:

> "I guess in our industry you are not trained to run a business, you learn by life experience. We are not trained in fiscal management, you are not trained to handle tax and invoices, government laws and regulations. We learn in other ways and the more you learn, the more you make mistakes. People will come in and say 'Don't do that, don't do that, do that, and that and that'. So that gets life experience. But that is the same in every industry; life experience is the way we all benefit as well as [formal] education." (A1801, 91:6)

It seems the only way to build TK is to get involved with the real business and accumulate experience which is difficult to acquire from formal training.

Learning is Making Knowledge Tacit Rather than Explicit

It seems that the end-point of the speaking-skill learners during the learning process was to make the skills tacit. At the start, a novice speaker would try to follow the

instructions of the manual or the mentor, and would practice what had been learned via speeches and evaluations. Eventually, a stage is reached where skills are performed with confidence until, finally, the skills are performed unconsciously. At this expert level, there is no longer the need to pay attention to the choice of skills or tools needed for a memorable, inspiring or interesting speech.

Expert speakers are also learning and building their new skills as novices do. For the speakers who have stayed in the speaking clubs for years, they have their own advanced manuals and challenges to sharpen their skills and learn new ones. What the expert speakers learn and practice is different for what a beginner does. The expert speakers have the inventory of certain levels of skills, and what they need to learn is to grasp some new skills based on what they have learnt, or to update their old skills with new ones. The latter is often more difficult than the former as it will involve a process of self-awareness, identification, judgement, trial-and-error, and as usual, confidence.

To summarise, three enablers were found by this research: conveniency, motivation and domain relevant knowledge from individuals. It confirmed that different industries picked up different knowledge and its representations. Most importantly, the research confirmed that TK is shareable either in various forms of language, including stories, metaphors, and cases, and visual representations. As knowledge users, differences between experts and novices has been observed in knowledge exploitation and sharing. By standing in the shoes of the learners, it is realised that practice makes perfect and learning is about trying to make unconscious TK explicit.

4.3 Finding 2: How Tacit Knowledge Sharing is Supported by Visualisation

The second set of major findings is concerned with how participants use KV. Sometimes they used these visual representations on a hunch, but they can choose various kinds of visuals for different purposes and situations. The research data reveal that not only does the knowledge in the visual representations matter, but skills in making the designs also matter. The benefits of visual representations are the accelerating power of problem-solving, creativity and innovation, and strategy

making and implementation. Table 4.2 outlines the main themes that are discussed in this section.

Table 4.2: Themes and Sub-Themes of Finding 2

Finding 2: The way Tacit Knowledge Sharing is Supported by Visualisation	4.3.1 A Tentative Taxonomy of Visualisation Formats	4.3.1.1 Node 1: Representational Graphics
		4.3.1.2 Node 2: Non-Representational Graphics
		4.3.1.3 Node 3: Numbers
		4.3.1.4 Node 4: Icon
		4.3.1.5 Node 5: Text
		4.3.1.6 Node 6: Table
		4.3.1.7 Node 7: graphs
		4.3.1.8 Node 8: Infographics
		4.3.1.9 Node 9: Conceptual Diagrams
		4.3.1.10 Node 10: Schematic Diagram
		4.3.1.11 Node 11: Geometric Map
		4.3.1.12 Node 12: Pretechnological Drawing
		4.3.1.13 Node 13: Technical Drawings
		4.3.1.14 Node 14: Visual Metaphor
		4.3.1.15 Node 15: Photos
		4.3.1.16 Node 16: Hypothetigraphs
	4.3.2 Different Industries Employ Different Visual Techniques	4.3.2.1 Industrial Differences in the Employment of KV
		4.3.2.2 Purpose Differences in the Employment of Knowledge Visualisation
	4.3.3 Contributions to knowledge visualisation by Mediaand Gestalt Law	4.3.3.1 Three Media were Used to Support Knowledge Visualisation
		4.3.3.2 Gestalt Law Contributes to Knowledge Sharing
	4.3.4 Four Situations where Visuals Fail for Knowledge Sharing	4.3.4.1 Availability
		4.3.4.2 Effort Required
		4.3.4.3 Time Required
		4.3.4.3 Accuracy
	4.3.5 Five Ways that Tacit Knowledge Sharing is Supported using Visualisation	4.3.5.1 A Picture is Worth a Thousand Words in Knowledge Sharing
		4.3.5.2 Factors Consider when Employing Knowledge Visualisation for Tacit Knowledge sharing
		4.3.5.3 Tacit Knowledge Sharing Using Visuals
		4.3.5.4 More Knowledge Visualisation Means More Creativity and Innovation
		4.3.5.5 Knowledge Visualisation can Help Novices Grow into Experts

4.3.1 A Tentative Taxonomy of Visualisation Formats

Borrowing from Massironi (2002), the visual representations that were observed in this research are presented in Figure 4.9. It was not the intention to create an exhaustive taxonomy, but rather to capture all the graphics that were either provided by participants or were observed being hand-drawn.

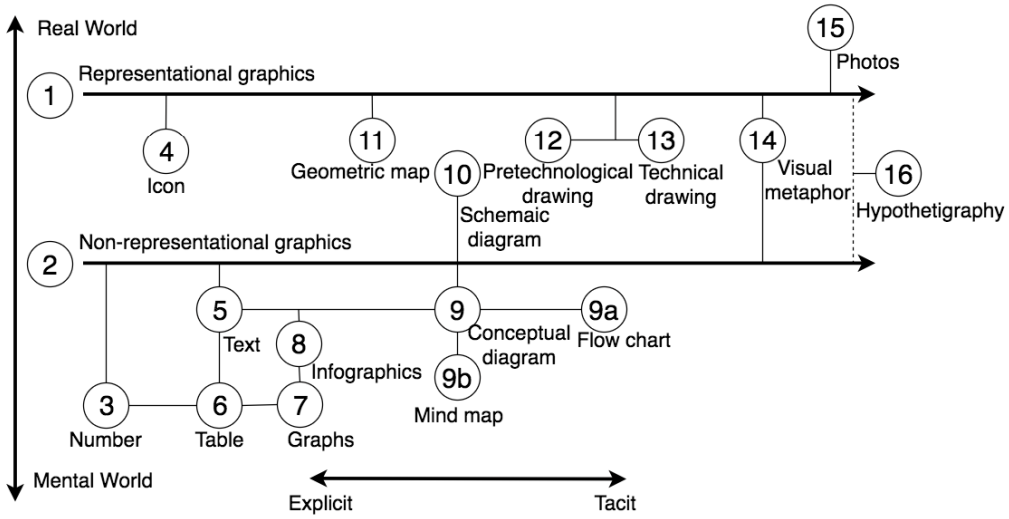

Figure 4.9: Graphic Representations Generated by this Research

The vertical dimension in Figure 4.9 spans the graphics developed from the mental world to the real world, as one proceeds from the lower to upper part of the figure. The area under the non-representational line collects all the formats that are based on numbers and text. The area above the representational line, in this case photos, represents snapshots from the real world. The area between these two lines comprises the abstract concepts with the real-world snapshots. For example, Node 11 Geometric map is a representation which can show the location and density of the real objects without any other irrelevant information.

The horizontal dimension spans graphics that become more complex in format, but more efficient in TK sharing, as one proceeds from left to right of the figure. The nodes and segments find their places according to the following rules:

- No node should lie directly on one of the horizontal lines, which emphasises that nodes are specific and singular;
- Each node has one or two connecting segments;

- Connections between nodes may be either direct, as shown by a solid line, or indirect, as shown by a dotted line;
- The position of a node is placed relative to its neighbours. If one node is higher than its neighbours, it should be more physical. If it is farther to the right, it should be more complex and TK related.

4.3.1.1 Node 1: Representational Graphics

Representational graphics include all the visual representations which can be closely related to their physical existence. For example, an icon is the simplified representation of the real object and a photograph is a two-dimensional replica of a real object. Hence, along this axis, the representations include more details from the real objects than the non-representational graphics, and thus have the potential to share more TK.

4.3.1.2 Node 2: Non-Representational Graphics

Non-representational graphics are the abstract parts of the representations of the real world, dealing more with language and logical reasoning. This research treats numbers and texts as knowledge representations. On the left side are numbers which reduce all the properties of objects into a quantity. Following number is text. Numbers and texts are not the focus of this research, but this research notices the complementary use of visual representations and numbers and texts. Also, there is an evolutionary approach starting from number to texts, table, graphs, infographics. The contribution of numbers and texts to this research cannot be neglected.

4.3.1.3 Node 3: Numbers

Numbers only represent the quantitative properties of objects, which are used by accountants or scientists especially. One way to utilise numbers is to put them into tables with some structure that makes them more meaningful.

> "If it's pertinent, what we've generally been doing is dealing with numbers. So quite often the issues or the answer is either black or white." (A1202, 76:2)

Another way to take advantage of numbers is to put them into formulae and finally into ratios, which help accountants to judge the operations of an organisation. Such techniques as employed by accountants to take advantage of numbers and involve testing and analysis without the need for pictorial forms:

> "So, a lot of what we do is about understanding and getting comfortable with how an organisation has put together that information. So, to do that we use testing and analysis. But a lot of the analysis is very formula-driven. It isn't really necessary to use graphics because we're trying to quantify variations." (A1202, 76:3)

Some of the scientists also employed indicators to simplify and make sense of a situation. Ecological indicators are very important for detecting changes in status and health:

> "In the economy, we have things like GDP. The kind of idea that a simple measure means something bigger than itself. So that's the tool that the manager would use to talk about states and environmental indicators." (A302, 12:17)

In this sense, numbers can communicate key points if structured and abstracted into formulas or ratios.

4.3.1.4 Node 4: Icon

An icon abstracts all the information into one key symbol to represent the core part of a message. Because of the abstraction, icons can pass the key message through very efficiently. One participant asserted:

> "In some way pictures will be very clear. If you draw a stop sign everyone knows what it means. Some pictures are very clear, and probably better than verbal communication because you can stop at the end of the road and shout out to someone they can't stop. But if they see the sign, they are going to stop." (A1201, 73:8)

As well as being recognised by most people it simultaneously makes people aware of its meaning.

4.3.1.5 Node 5: Text

Text is about the scripts which can be written and read by senders and receivers. Text can be complemented by other visual representations for efficient communication:

> "Because a picture tells a thousand words, graphics allow the reader to quickly assimilate the information you're trying to explain in the text, so it supports the text and the text supports the graphics. Rarely are graphics used to justify the text. What we say in the paper is supported here with evidence, because as scientists, our work will be peer-reviewed, so we need to justify what we say. The graphics are an effective way to present technical information." (A304, 23:6)

Compared with graphics, text is often less effective in terms of communication efficiency:

> "With pages of text, you need to flip backwards and forwards to try to build up the picture in your head. So, it's much better to just provide the picture and people can ask questions about the details." (A306, 40:4)

4.3.1.6 Node 6: Table

Tables, which mainly collect numbers or isolated information into a structure, can contain quantitative or qualitative sources.

Tables used for Quantitative Information

As mentioned in the discussion for node 3, a table is an efficient way of utilising numbers. Accountants often place numbers (quantitative data) into tables, which offer structure and opportunities for further analysis:

Tables used for Qualitative Information

Qualitative information can be placed into tables to achieve a structured information framework. For example, the speaking clubs use tables to organise meeting agendas; to take notes to organise evaluations; and to show comparisons:

Agendas

The activities in a meeting are often organised into an agenda with qualitative information such as a timestamp, activities, and participants. Figure 4.10 shows an example of an agenda used for one meeting in a speaking club.

5.20pm	Arrive and settle in	All	10 mins	Notes
5.30pm	Welcome to members & guests	Gautam	2 mins	
5.32	Word of the day	Monica	1 mins	
5.33	Introduction to first speech	August	2 min	
5.36	Speech # 1	Dave	10 mins	
5.46	Introduction to second speech	Frank	2 min	
5.48	Speech # 2	Maria	20 mins	
6.08	Table Topics	Cherie	10 mins	
6.18	Evaluation of speech 1	August	3 mins	
6.21	Evaluation of speech 2	Frank	3 mins	
6.24	Table Topics Evaluation	Chris, Eric	5 mins	
6.29	Grammarian evaluation	Monica	2 mins	
6.31	Time keeper evaluation	Paul	2 mins	
6.33	General evaluation	Helen	5 mins	
6.38	Trophy presentations		3 mins	
6.40	Meeting end			

Figure 4.10: Tabular Agenda used in the Speaking Clubs

Source: Participant (B1, 211:5)

An agenda presented in tabular format is a quick approach to share what will be happening during the meeting:

> "The whole meeting is very structured, and we like to proceed from the start to the finish in a set order. So, I put the agenda in this linear format, which is probably as good as a mind-mapping would be." (B103, 118:18)

This comment also indicates how a table takes higher priority of over a graphical mind-mapping technique.

Notes

As noted by one participant, who preferred tabular sheets to take notes and deliver her evaluations as she thought herself as having that mind style and education:

> "My preference is for a more verbal linguistic style of learning – I suspect it may be because I was not trained in this in my early primary and secondary schools, and obviously the foundational building blocks of cognitive learning skills and styles begin at a very young age." (B107, 268:6)

The advantages of using tabular sheets includes a clear structure to cover all the points and keeping the speaker on task:

> "I chose the Toastmasters General Evaluation Sheet because it gave me a very clear structure and ensured that I covered all the main relevant points. I have only done a General Evaluation once before, so I felt the support of this sheet, which was developed by an experienced Toastmaster, would provide a guide for me. The timeframe for preparing the Evaluation is tight, and the presentation time is brief, so I needed to keep the presentation crisp and to-the-point – I tend to be a bit 'wordy' so this sheet focused me." (B107, 268:7)

Categorisation and Comparison

Scientists were found to integrate tables into their publications to show the structure, mainly categories and comparisons, of selected information. Figure 4.11 shows a table from a published article. This shows a list of hydrodynamic forcing combinations used in the simulations and the associated peak depth-averaged current speeds. The speed outcomes for different situations: small tide only, small tide plus moderate wind, small tide plus moderate wind plus one waves… are also shown. Thus, the results for different tidal conditions can be readily compared.

Hydrodynamic forcing combination	Plot label, Figs 5–7	Tide ($m\,s^{-1}$)	Wind ($m\,s^{-1}$)	Waves	Off-shore ($m\,s^{-1}$)	Littoral ($m\,s^{-1}$)	Headlands ($m\,s^{-1}$)
Small tide only	*A*	0.05	0	None	0.05	<0.02	0.2–0.3
Small tide, moderate wind	*B*	0.05	4	None	0.05	<0.02	0.3–0.5
Small tide, moderate wind, Type 1 waves	*C*	0.05	4	Type 1	0.05	<0.05–0.45	0.3–0.5
Small tide, fast wind	*D*	0.05	7	None	0.05	<0.05	0.3–0.5
Big tide only	*E*	0.3	0	None	0.3	<0.05	0.3–0.6
Big tide, moderate wind	*F*	0.3	4	None	0.3	<0.05	0.3–0.6
Big tide, fast wind	*G*	0.3	7	None	0.3	<0.1	0.45–0.7
Big tide, fast wind, Type 2 waves	*H*	0.3	7	Type 2	0.3	<0.05–0.45	0.45–0.8

Figure 4.11: Tabular Representation in a Scientific Publication

Source: Participant (A304, 31:1)

4.3.1.7 Node 7: graphs

Graphs digest the numbers and convert them to lines or curves according to the combination of different axes. Figure 4.12 shows the trends of DAFB-Fresh Weight (g) for Brix, DM, Firmness, Insol and starch.

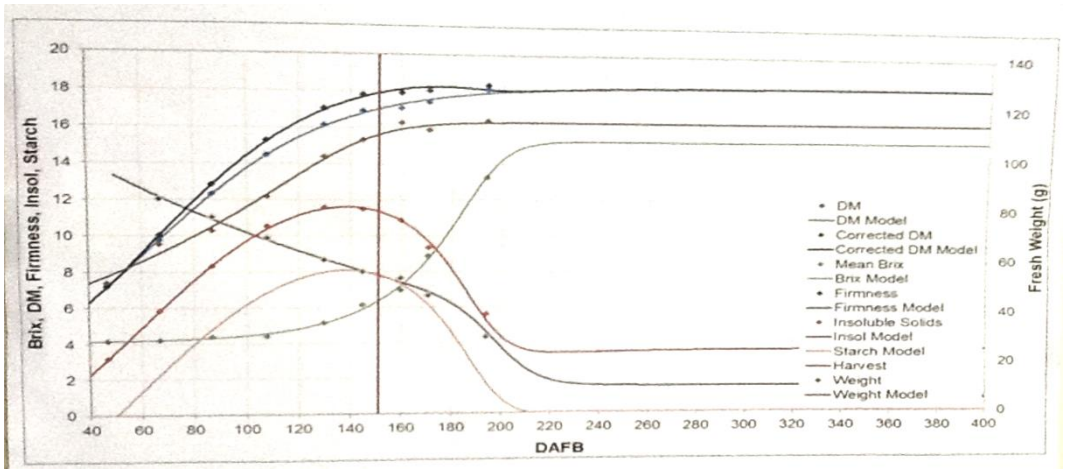

Figure 4.12: Graph Example Showing the Trends of Parameters

Source: Participant A503 (50:2)

As one participant explained, this type of graph is useful for quick communication, which is the advantage of pictorial representations over scripts.

> "See my wall, there's lots of schematics up there. This way to present information is very, very popular in scientific research. You try to get the overall method and what happened in a particular process, often looking at the temporal, special processes, so you produce diagrams like this. This is probably the most common way to convey the information because to try to describe all of that in words would take a very long time." (A504, 53:4)

People's preference for graphical representations was also noted when a scientist mentioned how he chose his way to present his messages.

> "You know it's just numbers, but I think people like visuals. You can look at a diagram, an exploded pie or a small bar chart individually and they will tell you that information. Although you can see the same numbers appearing in a table, it doesn't have same effect." (A504, 53:2)

Turning numbers into graphs can indicate trends or differences:

> "To show information about the way the sales of a business grew, we will show a trend chart with years, or months, whatever it is, and then share the trend with the sales and management team. Or if a business has four or five areas with different business streams, they might sell five different products. If two products sell a lot more than the other three we will use a graph to show those two products with a higher representation of sales." (A1201, 73:6)

4.3.1.8 Node 8: Infographics

Infographics typically integrate qualitative information with quantitative values. Figure 4.13 shows an infographic used by one participant on their website to showcase a newly introduced passive home solution: It contains key numbers, texts, icons, and shapes to convert the idea of free heating and cooling into a graphical form. Interestingly, it is noticed that text illustration is put aside the infographics to enhance the marketing idea.

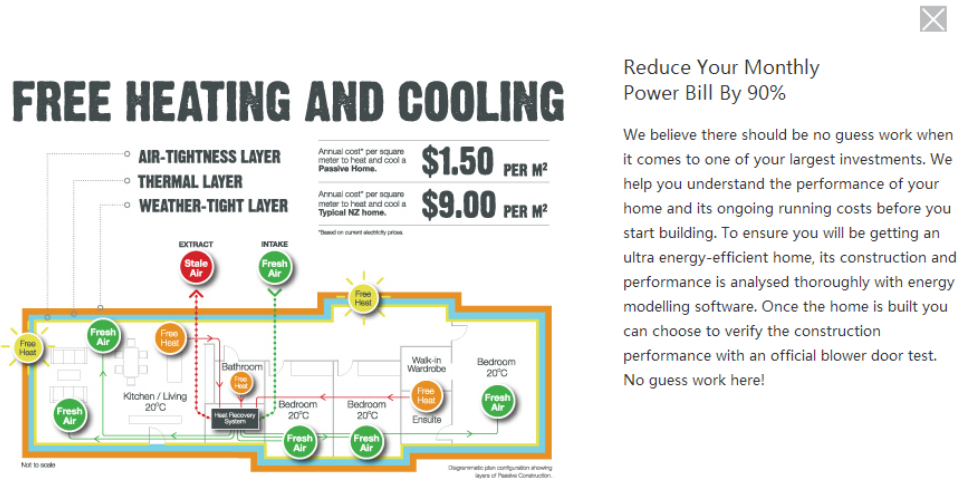

Figure 4.13: Infographic Example

Source: An architect participant (A1701, 95:2)

4.3.1.9 Node 9: Conceptual Diagrams

A conceptual diagram mostly connects concepts. It has more of an emphasis on concepts than the infographic. And unlike a schematic diagram, it limits itself to concepts rather than representations of the real world.

Diagrams

As one participant reported, diagrams simplify ideas and get marketing points to the clients:

> "I think diagrams are a reasonable proportion of what we do. A diagram can simplify the abstract and present the essential ideas as a kind of marketing to reach the clients. This is probably a little different from what the architects do." (A1701, 12:12)

Two varieties of diagram were found in this research: flow chart and mind-map:

Node 9a: Flow Chart

A flow chart incorporates more processes than a mind-map, thus it contains more details. Sometimes a flow chart can be arranged with temporal sequences, and sometimes it can be combined with logical sequences. For an example of the latter, one speaking club participant, who described himself as not being a visual person, preferred to keep a flow chart of notes as a reference for his later evaluation.:

> "Well it's how my brain works. I prefer the flow chart style which puts things in order but still has enough room for more notes. And [because it's in order] I can start from the top and think 'where do I start?' Starting from the middle obviously works for Maria as she's probably got the mindset to organise anything, but for me it's not the logical flow." (B101, 228:8)

A flow chart can also be used for problem solving by following a set of conditions under the guidance of the chart:

> "You might have a course of action that you've taken that may have 8 or 9 steps. A graphic representation of the steps helps you think through the way mange your approach or problem." (A1201, 73:19)

Node 9b: Mind-mapping

Mind-mapping was perceived to be an easy concept learn and use; its qualitative nature making it popular in many fields:

> "Mind-maps are mainly based on words, scoring how frequently the words are used in a conversation. These things are really based on very simple concept." (A302, 10:9)

As for the hierarchical structure of mind-mapping, one participant illustrated it with the simile of a branch of a tree:

> "Is it easy to pick up, yeah, I think it is because it's like a branch of a tree, you can relate them to that, you know, you've got your main branch, you've got your next size branch, the smaller one, it's a very easy concept because people are familiar with trees." (B103, 102:21)

The mind-mapping technique is useful because it can contribute to many functions like **brainstorming, planning, note-taking, pattern identification, and knowledge retention**.

Brainstorming

Brainstorming was found, in this research, to be used to answer the what-when-why-who-how questions, which involves organising related knowledge in the brain and then representing that as a mind-map:

> "When I'm brainstorming, a subject I don't know much about I just put some kind of subject heading in the middle. Then I just go around the what-when-why-who-how questions around the outside, and then think around the definition and when would it be important? Who would it matter to? Then that starts to give me some ideas about where to look for information or what pathway to follow; you know, to structure the project I'm doing. I found it's really useful for brainstorming a new area." (B103, 102:16)

The technique is useful because of the structure which simplifies the points and makes it easy to use:

Planning

Some participants use a mind-map as a planning tool, for the same basic reason as brainstorming:

> "I suppose if I was looking at planning a speech and I had, say, 3 main points I want to make in the speech, I would start adding the detail onto the first three branches. If I study that, then when I was doing a speech, I would go down one branch and think about 'Okay, what came off that branch?' You know, I've been able to do it because I had that visual picture for the structure." (B103, 102:9)

Notetaking

Notetaking is related to personal style, and mind-mapping provides an uncomplicated way to take notes:

> "I think notetaking is something quite personal to each person. Sometimes also we might be using a technique we always use without realising we could use a better one. I mean, when we were in school, you had the heading, maybe had a subheading then you would be writing, and then you have the next heading and subheading and so on and so on. [But] if I must go to a lecture now, I would mind-map my notes. If someone gives a good introduction and says what they are going to cover, you can then immediately have your main branches already headed up." (B103, 102:17)

Compared with traditional linear notes, mind-mapping notes make things easier and on the right track.

> "Yes, I think it does more than the linear style of taking notes because I don't know, it just seems it's easier to identify words in this kind of format, you can get lost when you're just writing long lines [of text]." (B103, 102:24)

Pattern identification.

Some participants claim that the mind-map structure makes it easier to identify similar patterns:

> "Maybe it's because they look more like a picture, I don't know. It would be interesting to look into pattern recognition aspects which means something you can bring out as [themes??]. This may actually help people expose patterns and allow [them] to identify them more easily." (B103, 102:25)

Knowledge retention

If organised properly, a mind-map can help retain knowledge more efficiently than can a bullet points structure:

> "It just depends on people's preference really. Just do two or three words as a mind-mapping and it's amazing how much knowledge can be remembered with a few words (A1201, 66:9).

However, if the structure of the information is not clear it may be difficult and even confusing to use mind-mapping:

> "I think interpreting a mind-map is quite complicated. I can recall one time that I was using mind-mapping on a whiteboard for a group discussion. It was about what things were pin points, what sort of things could we address in our program. We kind of broke of them down but it was difficult to end up with branches because you've got lots of branches. You've got chunks of writing at the beginning, so it gets really messy really quickly." (A306, 38:9)

For some circular structures, mind-mapping fails due to its hierarchical nature"

> "So many behaviours I've observed in workplace are not linear, they are quite circular. [So] you can't draw a linear construct or concept map that will tell the story because [the paths] go back and forth in a circular behaviour, and a mind-map per se starts from a central point. Although there's a linkage you can use to connect different ideas, my experience

> is that actually the structure of the mind-map itself doesn't lend itself to really making sense." (A101, 2:6)

4.3.1.10 Node 10: Schematic Diagram

A schematic diagram incorporates more representational information from the real world, so can contain more detail than conceptual representations. Figure 4.14 shows how one participant used a schematic diagram to highlight an important feature and make it stand out from other features.

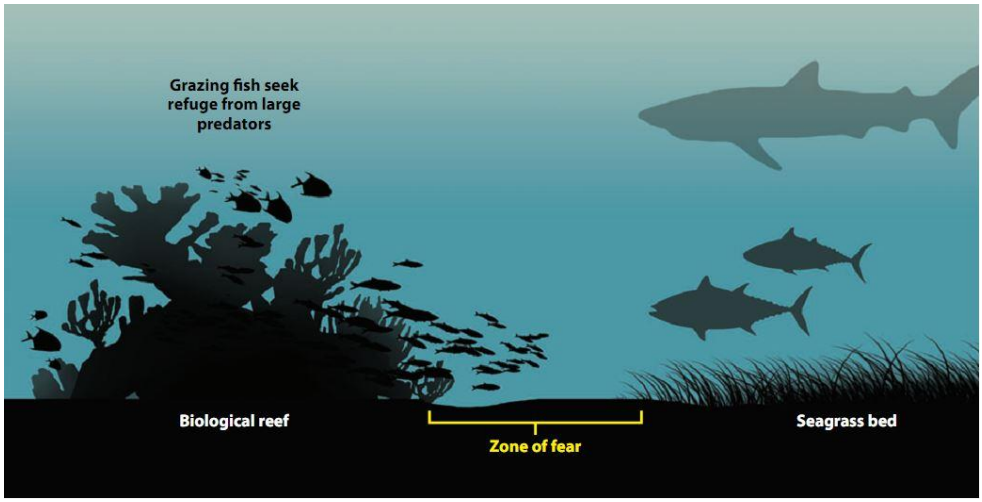

Figure 4.14: Schematic Diagram

Source: Participant (A302, 16:7)

Using graphical representations was observed to help the scientist participants rebuild the context and get the main message across easily:

> "We are trying to step people through some quite complicated ideas in this paper. But graphics help to illustrate the points and bring out the key concepts." (A302, 12:4)

4.3.1.11 Node 11: Geometric Map

A geometric map contains information closely related to physical location. Such a map shows information, without which it would be much harder to understand. One scientist participant used Google Earth™ to develop a 'Trap-Data Viewer' that allows users to explore the locations of traps installed in a valley, Figure 4.15.

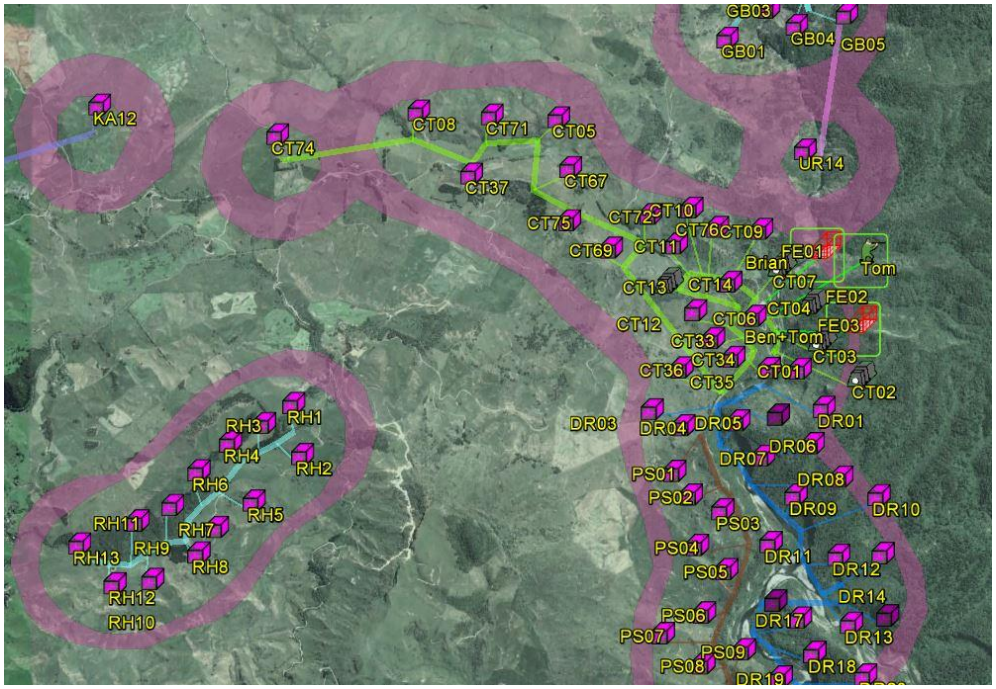

Figure 4.15: Google Maps used by a Scientist

Source: Participant (A503, 50:5)

The participant thought it was extremely useful to put the geometric information into a map that provided a convenient way to explore and share the project:

> "I think it makes the text much easier to understand, because this is about geography, about places and space, and maps, and so it's really hard to do it without providing the context." (A303, 18:10)

4.3.1.12 Node 12: Pretechnological Drawing

Often used for surveying or designing, pretechnological drawings are conceptual illustrations of an object to consider the possibility of its construction. Figure 4.16 shows a pretechnological drawing concerning the possibility of combining various components into the construction of a multi-function airplane that could be used for spraying, surveying, or skydiving. One of the challenges was to install the components onto a common fuselage base.

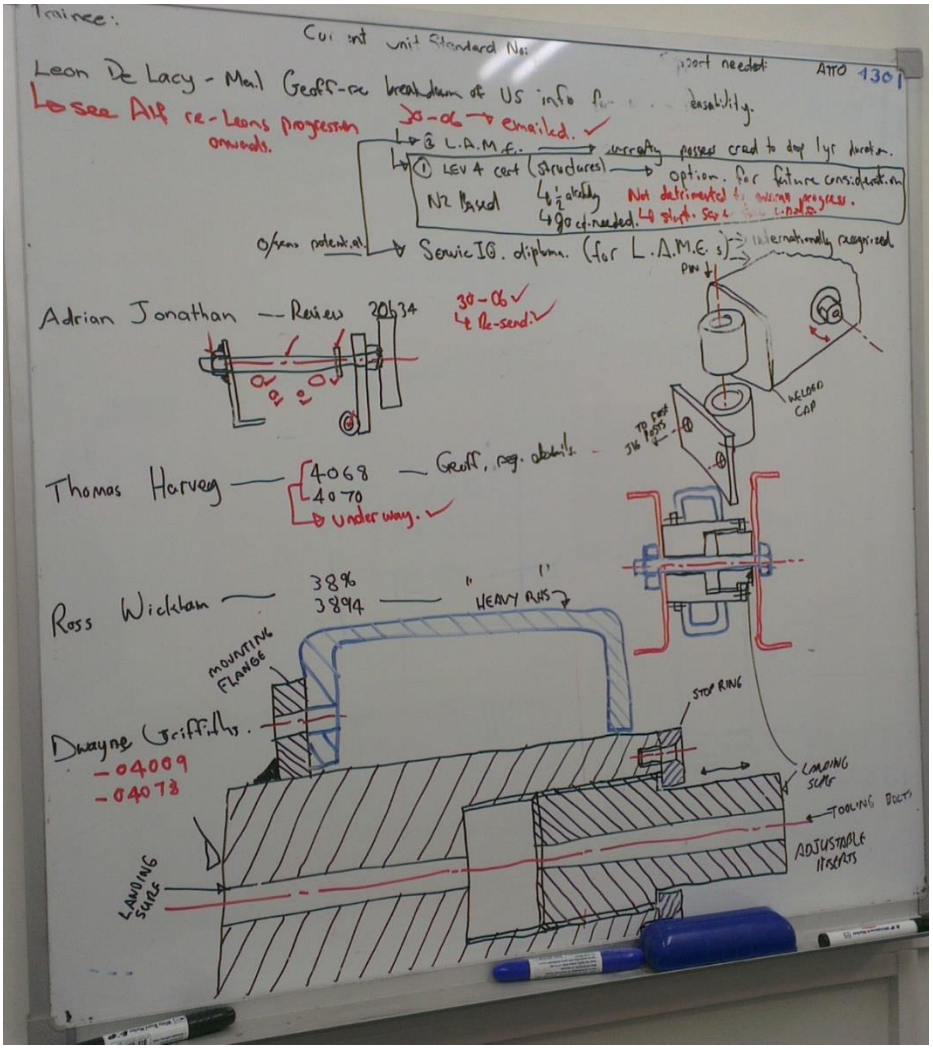

Figure 4.16: Pretechnological Drawing Showing Possible Solutions

Source: Participant (A802, 257:1)

When being interviewed, the participant shared the story, which he illustrates by drawing on another illustration:

> "Before the [pretechnological] drawing I had already formulated a solution of how it could possibly work. So, I just drew that on the whiteboard, and that basically became the solution we followed. I also had alternatives in my mind about how the mechanisms could work easily, but the design team chose another path. I couldn't understand why, because I thought an XXX mechanism would be superior and a lot quicker… [at this point the participant reaches for another drawing and begins drawing on it - please refer to earlier Figure 3.4]." (A802, 71:6)

This participant has the habit of drawing his ideas down frequently which he thought of as being the interactions between the representations and his mind:

> "…By the time I finish the sketch I've already developed four versions of the ideas, and gotten rid of 3 of them, because version 4 overcomes all the problems that version 1, 2, and 3 already have. Ok, so that's the essential learning process right there." (A802, 71:23)

Sketch

The common name for a pretechnological drawing is a sketch. Sketching can be used to generate ideas quickly and easily by architects:

> "I think generally you start with sketching, sketching is the quickest way to think about ideas so is commonly used." (A1701, 88:2).

One scientist participant echoed same preference for sketching.

> "I might be sitting with someone, talking about elements what we've been doing, and just sketching what we were talking about, that's the simplest." (A302, 8:25)

Hand-drawn sketches on whiteboards were very common throughout this participant's organisation (scientist office). An example is shown in Figure 4.17.

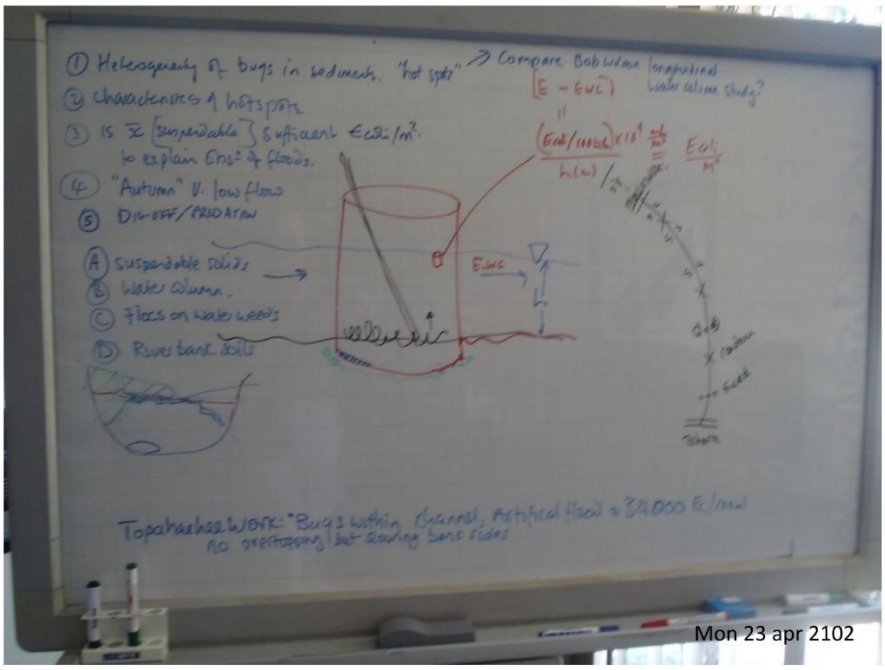

Figure 4.17: A Whiteboard full of Sketches

Source: Participant (A301, 9:1)

Depending on peoples' choice, sketches commonly appear on whiteboards or on paper, in personal offices or in meeting rooms as an essential way to communicate:

> "Sometimes it would be handy to just be able to do a brief sketch there and then [on paper]. I had in the past used the whiteboard that's in the tea-room for that purpose." (A304, 21:9)

Some participants like taking notes as sketches to connect different things together, to see how they fit.

> "So, I make notes, but I like to draw sketches, so sometimes I draw a little flow chat-sketches to see how things fit together." (A303, 16:11)

4.3.1.13 Node 13: Technical Drawings

Technical drawings are the representations that engineers and architects use to communicate their ideas, or give the concepts physical existence. Figure 4.18 shows two technical drawings and some notes for discussion or reference. In a typical situation, a technical drawing conveys knowledge that normally cannot be achieved by verbal language alone.

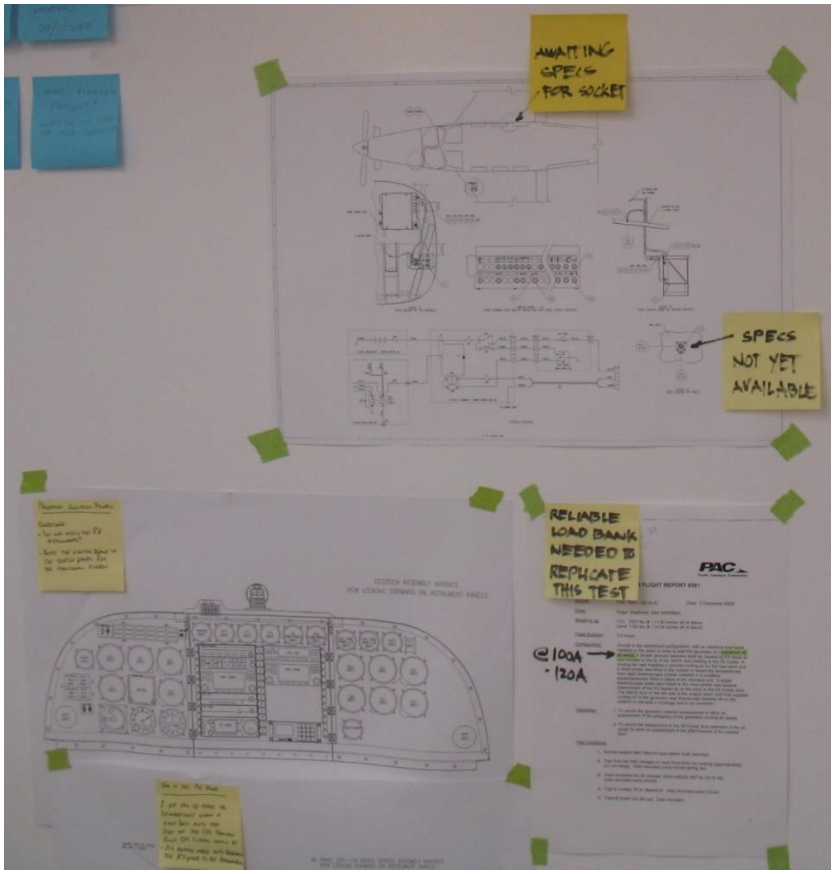

Figure 4.18: Technical Drawings Observed at Organisation A8

Source: Participant (A8, 65:2)

4.3.1.14 Node 14: Visual Metaphor

A visual metaphor is the representation of a person, place, thing, or idea by means of a visual image that suggests an association or point of similarity. In Figure 4.19, a thermometer is used to indicate the changing situation of a healthy workplace culture. The similarity of temperature increasing and culture becoming better is shown by the thermometer.

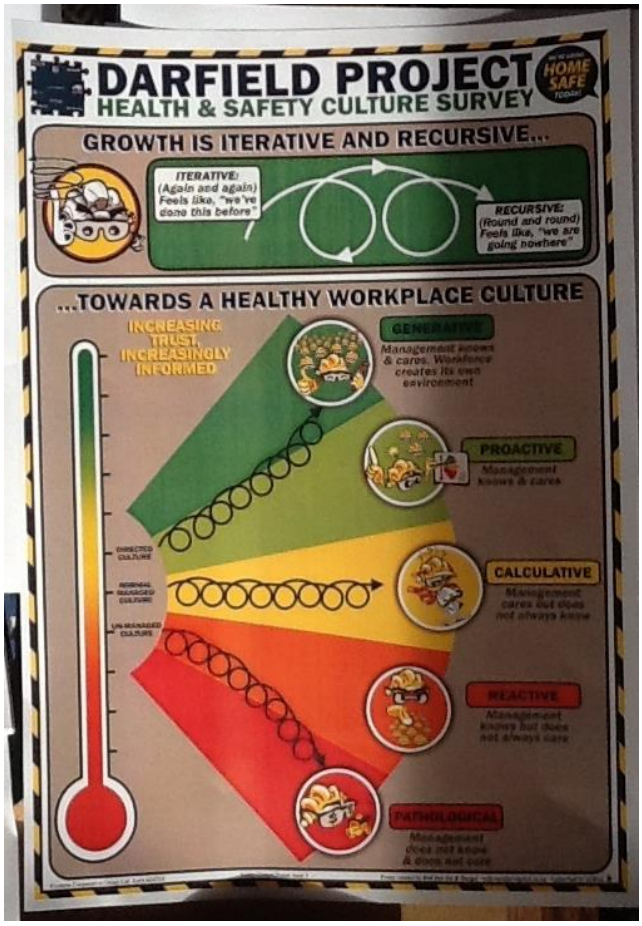

Figure 4.19: Visual Metaphor Example

Source: Participant (A101, 5:4)

The reason to choose a visual metaphor is its convenience, compared to the inconvenience of communicating the same idea in words. In Figure 4.19, organisational culture is often tacit and hard to express, so relating it to a thermometer makes it much easier to explain to other people. On the other hand, it is sometimes difficult to directly relate ideas to physical objects. Higher temperatures indicate an increase of conflict and instability. The purpose would be much better served if the thermometer indications could be reversed, the orange and red at the top and the greens at the bottom.

4.3.1.15 Node 15: Photos

Photos, which are often very convenient to take, show richness of details without any abstraction. One scientist participant used the photo in Figure 4.20 to illustrate the growth levels of four plants under different stress conditions.

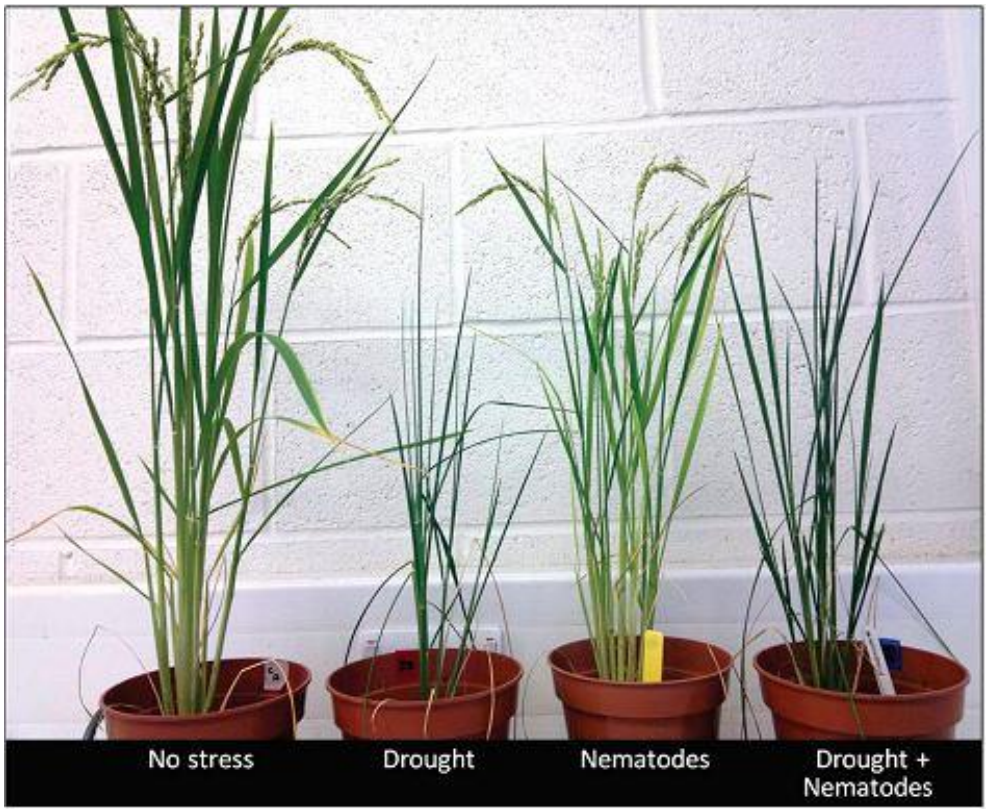

Figure 4.20: Photo used in a Scientific Publication
Source: Participant (A504, 54:4)

4.3.1.16 Node 16: Hypothetigraph

A hypothetigraph illustrates the world we directly observe by graphical representations, such as drawings, that present hypothetical, invisible, abstracted ideas. These worlds may be at the micro-world or macro-world level.

Micro-worlds are too small to be observed directly such as when the scientist participants are working on genes; they have difficulties showing other people what genes are like and their experimental approaches with them. In this situation, they need to convert what is unobservable into something people are familiar with, to communicate what they know. One participant (A401) was working with a team on the study of human inflammatory bowel disease (IBD), using mice. Figure 4.21

shows photos of colon tissue sections at 20x, 100x, and 40x magnification which are representations the scientists are familiar with.

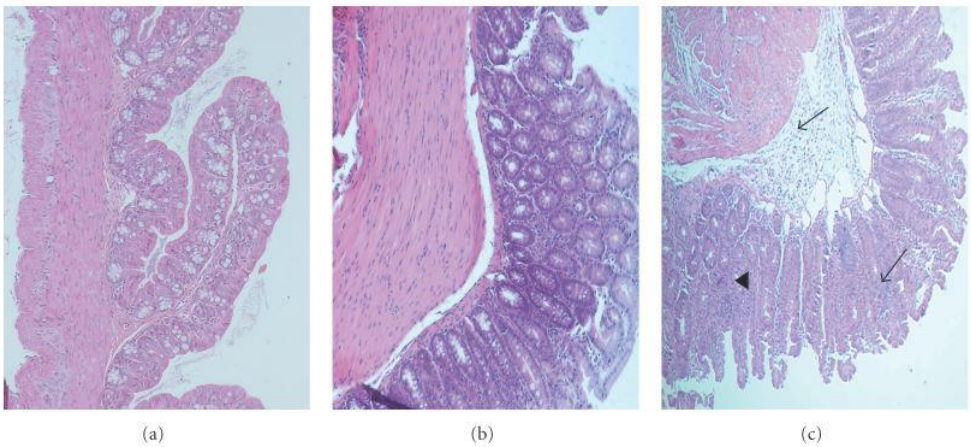

Figure 4.21: Colon Sections from Different Situations

Source: Participant (A401, 43:3)

However, the genes themselves are impossible to observe or illustrate as explicitly as body tissue. Instead, specialised software was used to provide researchers with an initial biological interpretation of the gene clusters. By comparing the colour ribbons shown in Figure 4.22., representing the separate groups of data, the scientists confirmed that more changes happened at 12 weeks than at 7 weeks of age.

The heat map in Figure 4.22 has three dimensions: samples, genes, and colours:

> "We have to colour that because it represents different things. We explain three dimensions of data here. We've got samples with one dimension, we've got genes with another dimension, but the genes and samples don't tell us much, right? But the colours tell us how highly one gene is expressed compared to another." (A401, 42:1)

To create such a diagram, its creator needs the ability to set up the hypothesis, design the experiments, use appropriate software and read output patterns, make decisions on which diagram is important to complement the text, and put that diagram into the most efficient form to achieve its purpose. Hence, some of the knowledge is tacit; for example, reading the messages exposed by Figure 4.22.

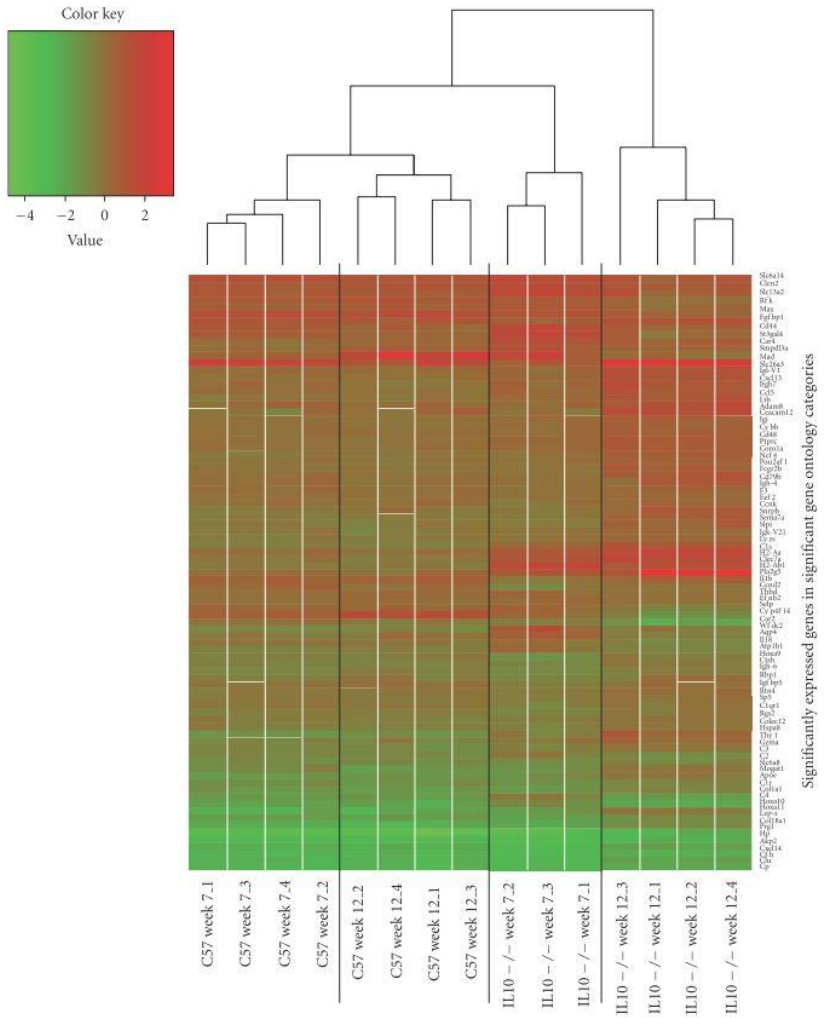

Figure 4.22: Heat Map Example

Source: Participant (A401, 43:1)

The heat map is important for the scientists as it helps them to share their IBD knowledge. It serves as proof and support for their conclusions with this IBD experiment, which adds credibility by showing how these scientists reached their conclusions; which is why the scientist group chose to communicate their findings with the necessary data analysis process also described.

Turning quantitative research data into coloured ribbons makes it easy for readers to interpret and compare what is going on when they read the published article. To understand what the diagram is really trying to say, it is often necessary to put the diagram into the context to obtain all the what-, why-, how-, when-, where-, and what else- information.

A knowledge of how to read the diagram and how the biology works can make the perception of this diagram more accurate:

> "If you are reading this paper, it kind of assumes you have some knowledge of molecular biology to understand it. If you were in that field, you will pick it up [easily]. Like the context is very specific." (A401, 42:2)

What is meaningful for a reader is not only the explicit new knowledge contribution to the field, but the TK; such as how to design the experiment, how to interpret the data, how to put that into diagrams, and how to write the report. From a reading of the article, without discussing it with the authors, the reader receives the explicit form of the knowledge, which is reinforced by the tacit form. This knowledge will be integrated into the scientist's networks, awaiting further tests that might support it.

It is easy to imagine that an expert will read the experiment report more quickly and more accurately than a novice or outsider. Furthermore, at the group level, the scientists may have knowledge of what should be done, the way it should be done, and whether the result satisfies the individuals. The agreement of the group becomes the embedded knowledge and encoded knowledge.

However, it seems that the reader cannot obtain TK directly from the EK form, but must turn the explicit form into the tacit form by using it with their own practices. Thus, shared knowledge, whether in tacit or explicit form, can be treated as the knowledge source and eventually it will become TK and EK combined.

This section has described, with the aid of examples, 16 forms of visual technique that were observed during this study. These were presented on a coordinate matrix of mental-real and abstract-complex (earlier Figure 4.9).

4.3.2 Industries Employ Different Visual Techniques for Varied Purposes

If it is accepted that knowledge is tied to agents, actions, and goals; the agents are the users, the goals are decision-making, problem-solving, etc., while the action involves producing visuals, making sense of them, and taking related action to achieve those goals.

Workers in different industries employ different KV techniques, Table 4.3, which was amply demonstrated in the preceding subsections. For instance, it was explained how architects and mechanical engineers prefer to use sketches and drawings, while scientists prefer graphs and photos. Because the architects and scientists are at the extremes, more emphasis is placed on those users in the following discussion.

Table 4.3: Different Industries Favour Different Knowledge Visualisation

Industry	Context	Purpose(s)	KV Format(s)
Science	Publication/ Presentation	Knowledge Sharing	Graphs, Images, Photos, sketches
Architects	Meetings and handover to builders	Clients' needs defining, discussion, passing to next workflow	Drawings
Insurance		Clients' needs defining	Tables (with quantitative information)
Law Consultant	Meetings	Clients' needs defining	Sketches (with qualitative information)
Manufacture	Meetings and handover to manufacturers	Problem solving, Refining client needs	Drawing
Software		Planning, problem solving	Sketches
Speaking Club	Presentations	Note-taking	Sketches, Mind-mapping

4.3.2.1 Purpose Differences in the Employment of Knowledge Visualisation

It was found that all the studied industries display differences regarding the knowledge receivers, their specific knowledge, and the way they interact with the outside world.

4.3.2.1.1 Knowledge Receivers.

It seems important to examine TK sharing from the recipient perspective. As a speaking club participant mentioned stated:

> "The other thing I think is to learn what helps the audience to remember what you will be saying. So, you learn to structure your speech with your audience's mind rather than just thinking how you want to get the

> information across. You learn to look at the other side of how they are going to be able to remember the speech, so you learn to look at it from the audience perspective when you construct your speech." (B103, 118:4)

Scientists need to employ a variety of visual techniques and media to make their knowledge accessible. The receivers of this knowledge are colleagues with similar backgrounds, readers with an interest in the research field, government representatives with some related knowledge, and others that have a passing interest to know about the field. Since these diverse groups have different levels of understanding of the related topics and concepts, scientists believe it important to share their knowledge via KV formats that cater for the needs of their recipients:

> "Technical people, such as technical people in regional councils interested in maintaining water quality standards, are the type of people who can read this [report]. But if a member of the public just comes in, it's pretty hard to for them to understand. They will understand the introduction and some general things out of it, but it will more difficult for them when it comes to the terminology. So, if you want to take the same story to the public, you have to present it in an unusual way." (A303, 18:16)

To communicate with the different stakeholders, different techniques and languages, are employed:

> "I think personally that some people, such as mathematicians, tend to think in numbers, whereas biologists, ecologists, and teachers often tend to think in diagrams. If I was writing a paper for a specialist audience I might include more numbers. But if I was trying to communicate the meaning to a client, business person, or member of the public, I would try to use diagrams." (A305, 35:1)

For architects and engineers also, when the knowledge recipients are clients, colleagues and co-workers, it is natural to use the working language of drawings. However, architects also have many clients and third-party interactions with laypeople, when clearer, more generalised KV formats become the first choice.

4.3.2.1.2 Knowledge on the way

Scientist participants expend time and effort to reach embrained knowledge in the form of theories, formulas etc. on the individual level, while on the collective level it will turn into encoded knowledge as written rules or procedures. Architects put

their embodied knowledge into drawings which are very personal and experienced-based.

4.3.2.1.3 Ways of Interacting with the outside World.

Due to the different knowledge recipients and their existing states of knowledge, the ways to explore the outside world and accumulate knowledge were different; i.e. the ways of interacting with the outside world were observed to differ. The main methodologies employed by the scientists involved experiments to test hypotheses and draw conclusions from the experimental data. Architects, on the other hand, rely on personal experience and intuition; when they need innovative ideas for a design they might travel to see unique designs, talk with people to exchange ideas, and borrow ideas from artworks.

The ways of sharing knowledge with others were also observed to be different. For scientists, the main way to share their knowledge was via publications, using clear expressions and proven facts. Architects shared their ideas mainly through drawings, which on occasion can be difficult to express the ideas to laypeople. Sometimes they asked for a leap of faith from their clients to trust in the architects' expertise.

4.3.2.2 Knowledge Visualisation: Purpose Differences

KV was observed to be used for five distinct purposes: refining client needs, clarification, decision-making, problem solving, and brainstorming.

Refining Client Needs

Architects need to match their choice of visuals to the needs of their clients:

> "We don't have a set process. Some clients are not interested at all, some are able to understand the design better through a computer model fly-around. Others find a physical model easier to understand. We are dependent on the clients" (A1701, 88:5)

However, the complementary use of all communication channels seems more reasonable for architects, which was also found to be true in other industries studied:

> "As the clients explain what they want, we will put that into our own words, and our graphics will show how we have interpreted what we believe the client has said." (A1801, 91:8).

In Figure 4.23, a whiteboard with sticky notes, sketches and scripts was employed to refine the client's needs. According to this complementary use of communication channels, what the client (Mr. Wu) primarily needs in an airplane is to be suitable for spray use, with a secondary need for survey and photo use.

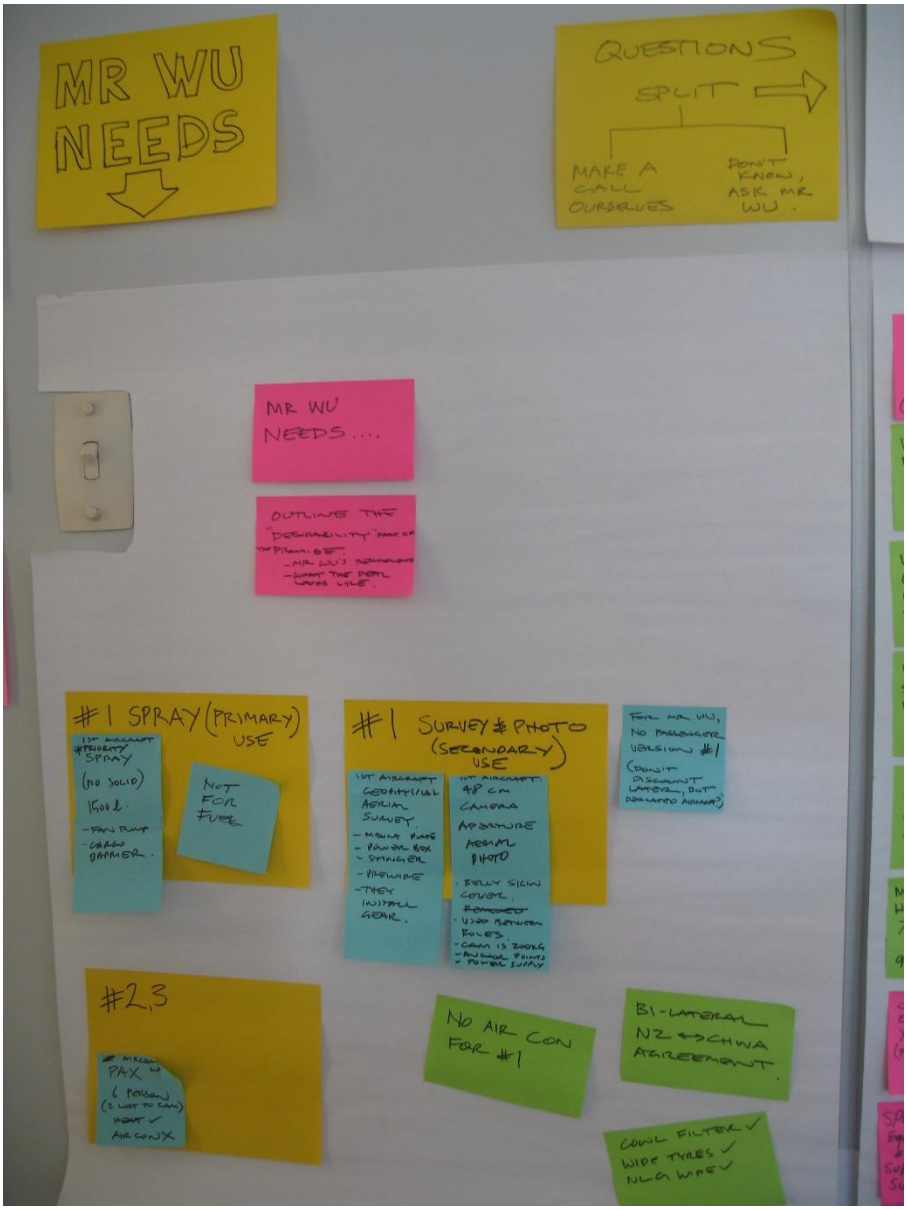

Figure 4.23: Sticky Notes for Refining Client Needs

Source: Participant (A801, 65:2)

As the essence of communication, graphics are there to transmit the senders' ideas. Senders can examine their communication approaches, which will help them provide a better encoded message:

> "So, graphics are more to support verbal and script explanations. It is better to combine them because when you look at something, you look

> at the verbal side of it, you look at the script side of it, you can look at the graphical side of it, you can mount them together, you can get the idea across, and our job is to get the idea across." (A1801, 87:1)

Clarification

For basic visualisation a simple drawing may be sufficient. However, for communication that involves clarification to avoid misunderstanding, a more detailed rendition is needed. As one participant reported:

> "If I'm drawing it for myself you won't see a picture, you will see just some central lines and some dimensions. But, if I am trying to clarify, you know, getting the objective view of what the design idea in my head looks like, then yeah. I'll put it down onto a piece of paper." (A802, 71:9)

Decision-Making

Visuals can be used to organise different information into one picture that contains prioritised value points and synthesises different viewpoints-which in the sender's eyes simplifies complex situations. Having this in one picture facilitates decision-making as it takes people less time to comprehend:

> "[It will show that] people from the town will get a good economic return and then we would focus on that value point. So that's a decision made all in one picture. It's what I mean to simplify because otherwise we could talk for months." (A601, 56:4)

Quality visual representations can help the decision-making process and facilitate the process by presenting a clear statement of the problem and potential solutions. This give the decision makers confidence:

> "People who have control over the finances will make decisions on the budget and whether they can provide funding for the idea 'because all solutions cost money to implement'. If I don't know the business well, I must say, 'Okay, this is my idea for the solution', and the clearer I can make it to them, the better the idea they're going to have about what this solution is about and what it might mean for them to implement it." (A802, 71:1)

Problem Solving

One engineering participant thought it was critical to visualise the problems in his head many times and sketch alternative solutions before he could achieve the best

solution. He concluded that visual representations can help him to be objective, looking at the workable solutions from other perspectives:

> "When there is only a limited range of standard engineering connectors that you can draw from, and your connector has just failed, you need to the ability to be objective and look at the problem that's in front of you and to visualise the solution. That's what important." (A802, 71:35)

Because visualisation in the head is thought to be easy for individuals, it is judged important not to overthink the solutions:

> "You know, the simplest things are often the best solutions. I see a lot of people who tend to overthink solutions for problems, they may get bogged down overcomplicating the process, sometimes I do it myself." (A802, 71:8)

Brainstorming

Brainstorming was observed to be very popular at the initial stage of a project or in a training session. Sticky notes or whiteboards can be used to collect participants' ideas onto a screen, invite people to contribute to the same target, and then reach the solution or agreement:

> "In the training session, they get together and write their ideas down, and we put that on the big sticky paper with more labels. Then I go through. I do a little bit of a sort and then we discuss the topics on the list. It's really good… seems very old-fashioned and low tech, but it's really very, very good." (A303, 18:23)

Reducing Workload

Visuals can summarise information into a picture and present it to the audience with just a glance. Some scientists employed graphics to reduce several pages of text into an organised picture:

> "You are going to extract the information very quickly. Particularly in papers like this, which is a synthesis or a review kind of paper, the graphics help strategically so you are not faced with 10 pages of text. It's not a novel you know." (A302, 12:13)

To summarise, the research data show that there were big differences in knowledge receivers, in their specific knowledge and in the ways of interacting with the outside world. KV has been observed to be employed for different purposes such as client

need refining, communication clarification, decision making, problem solving, brainstorming, and reducing the workload.

4.3.3 Contributions to knowledge visualisation by Media, Relationships and abstraction

Three types of media that support KV, namely: mental, physical and digital are presented here using evidence from the research data. These media plus the graphical formats described earlier, contribute to the various visual representations.

4.3.3.1 Media Used to Support Knowledge Visualisation

As used here, a medium refers to the intervening substance through which sensory impressions are conveyed. Three media types were observed in this research: mental, physical, and digital.

Mental Media

A mental medium refers to the stories, metaphors or cases which produce images inside the receivers' brain, as part of the decoding process:

> "There is a lot of information in a picture like this... water running around a beach and a spring bubbling. I tell a story in here about the spring bubbling around the beach but most of the people will see the picture, and I think they will remember. If I just used words, by tomorrow they would forget; with the picture, they will probably remember for a month." (A303, 16:12)

In scientific publications, stories are an essential knowledge sharing medium. Some scientists were observed to employ visuals, either graphs or photos, and to weave their stories, in order to pass their individual knowledge to the community:

> "The graphs show the measurements and make the points I showed earlier. Then there are these photos so people are going to get the impression of what the beach is like. The whole report has basically got lots of graphics because they are essential to tell a story." (A303, 16:8)

For the knowledge holders, one way to utilise their knowledge is to visualise the solutions to the problem in their minds, which often happens automatically. One participant described his imagination, or incubation, process as:

> "Sometimes you just need to back off, like clear your mind a little bit, and then just re-visualise stuff over again. Because it doesn't cost anything to visualise something." (A802, 71:8)

One difficulty of using the mental medium is that memory fades away easily:

> "And some of the best ideas are intuitive, you just get a flash, right? And you write it down because if you don't capture it, it's gone. You can generate them, and think about that at lunch." (A802, 71:36)

Physical Media

Physical media are the physical materials that are used to transmit information. In general, they are a physical object that can be touched. Whiteboards and sticky notes are used widely in business, so are described here.

Whiteboards

Whiteboards can be used to facilitate the knowledge building process:

> "I use a whiteboard to draw simple diagrams or write bullet points, one or two key words. That's enough trigger for me to continue to know what I mean to build on that." (A1201, 65:21)

Whiteboards can also be used for personal or group communication, and offer the chance to review ideas critically. The writer can record ideas on the whiteboard then change her perspective to that of a third-party, looking at what has been written down from a fresh viewpoint. This evokes more critical thinking and robust outcomes.

> "The pictures that I sent earlier, are of the information I write to my boards for project organisation, but there are also visualisation activities present where I am manifesting what I am imagining as a possible solution for the development in workshop manufacture. I draw the images so I can then assume an objective position with them, and over time as I work on other things, I review my thinking and add to the drawing developing a more evolved idea before going into expenditure on materials and time." (A802, 254:1)

The whiteboard provides a straightforward way to sketch out ideas and is a channel to communicate ideas. As shown in Figure 4.24, distinct colours, curves, shapes, texts, and numbers may be combined to facilitate explanation and progressively strengthen the points that are being made during the discussion.

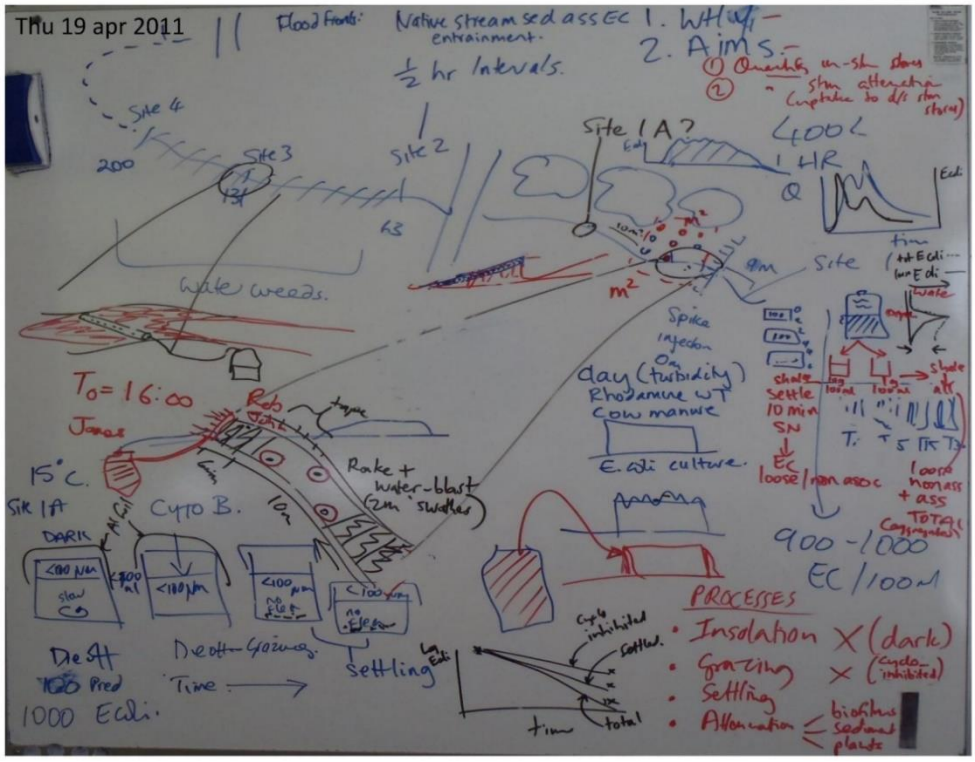

Figure 4.24: Colours, Curves, Shapes, Texts, & Numbers for Discussion

Source: Participant (A301, 9:2)

On the other hand, a whiteboard has shortcomings:

Lack of Privacy

Whiteboards are often located out in the open, which can raise privacy and confidentiality issues. In one case, an entire large wall was painted into a huge whiteboard, requiring a curtain to hide part of its contents.

Hard to Comprehend

It was observed that those who had participated from the beginning of a group discussion, had no difficulty picking it up again from the contents of the whiteboard. As discussions progressed, participants were observed to delete less important points to retain what is important. They could even tell the story of the discussion to that point. On the other hand, the contents of a whiteboard can be difficult to understand if one was not involved in the discussion from the beginning:

> "It's quite hard to follow if you haven't been involved with the whole discussion process, especially for the outsiders. There are usually no clues to show the sequence, or to indicate redundant information." (A401, 42:8)

Sticky Notes

Sticky notes enable users to write information on a small piece of paper, and attach them to any place which is convenient for the users to see. Sticky notes have many uses, including brainstorming ideas at the initial stage of a project:

> "Yeah, so it might be at the beginning in terms of what you want to get out of a particular session. At the end, I might go back to the wall to see whether we have covered all the sticky note items. That's very much in the training environment not necessarily when we're doing a job with clients." (A1202, 69:5)

One mediator participant encourages his clients to use sticky notes to combine their thoughts and show them to other people:

> "Bigger groups of people would be using sticky notes. We think it's a useful way giving people some time to consider… and think about their own feelings and work out how their own feelings fit their relation to the situation being discussed." (A601, 54:9)

The main shortcoming of sticky notes, apart from sometimes being hard to read, is that because information comes from diverse sources synthesis is always needed"

> "I found it is very useful for collecting information from people. But it is not good as a way to disseminate it, too frustrating. Little pieces of paper, you can't read what's on them when they are on the wall, and they are not repeatable." (A101, 2:7)

Sticky Notes and Whiteboard in combination

A combination of sticky notes and a whiteboard was found to be the most common general technique to encourage group discussion. It enables everyone to contribute their individual ideas onto the sticky notes and then place them onto a whiteboard. The whiteboard provides a whole framework to collect all the ideas:

> "It's great because it captures the ideas as they come out. You know if you capture an idea and throw up on a wall, then you can look at it and revise it. You can decide about that idea, a bit further down the line when things are a bit more developed. So, you can decide whether to park an idea because the essential thing about using sticky notes on the wall is that they make it difficult to miss the ideas that come out." (A802, 71:37)

Digital Media

Digital media are any media that are encoded in machine-readable formats. Deciding on their use requires special considerations, which are highlighted here through discussion of electronic whiteboards, presentation software, tablet PCs, and websites.

Electronic whiteboards

When available for real-time communications, sketching on an e-whiteboard was observed to be the participants' preferred option. Its output can be printed:

Presentation Software

Presentation software is a computer software package used to show information, normally in the form of a slide show. Microsoft™ PowerPoint is one main choice, which facilitates presentation in a linear way.:

> "I facilitate and help deliver a level 7 short course paper to nurses, mostly with PowerPoint. It is very linear, and a few of us have got really good PowerPoint skills…usually use bullet points plus some pictures, or some images from the internet, graphs. That sort of thing is really standard." (B103, 102:22)

The benefits of PowerPoint were recognised and the software was considered a tool which can help communicate ideas to other people.

> "[PowerPoint] is a great tool. Not intuitive but it's great if you're going to present an idea to people, then you need to convince them that the idea is correct or what to do, or you need to convey as much clarity as you can of the idea to them." (A802, 71:63)

Tablets

A tablet computer, commonly shortened to *tablet*, is a mobile PC, typically with a mobile operating system and touchscreen display in a single thin, flat package. Being portable, tablets are convenient to use. An Apple iPad can have many different applications (APPs) installed and can be used almost anywhere, anytime. The visuals can also be shared and stored easily:

> "He mind-maps on his iPad; that's just how he operates. He will go to a meeting, it might be a discussion around KPIs, or a technical issue, or

> accounting issue. He might sit down and need to talk through some of the financial issues with the mind-map up on the screen…" (A1201, 66:10)

Websites

A website is a set of pages of information on the internet about a subject, published by a single person or organisation. Users access websites when they search online and interact with it as needed:

> "We have a responsibility to support councils with water safety information about all of the beaches around New Zealand. Of course, there is not enough money to put a surf lifesaving club on every beach. That safety information is available on our website, so anyone who has an interest can have a look…so if somebody is going to a beach, they could look on the web and see what the beach situation is." (A303, 18:6)

Combinations of Media

The media discussed above may be combined. A recording whiteboard is a whiteboard which can produce digital pictures. Its large interactive display connects to a computer and shows images thrown by a projector. This mounted or freestanding whiteboard mirrors the computer's screen, and the user can control the computer by interacting with the board using a pen, fingers or a supported input device. Output can be printed and shared electronically.

> "Although I said creating a whiteboard is good and emailing a whiteboard is good, what meets our needs is a recording whiteboard. So, we record the whole session, you have the audio, and you can watch on the whiteboard as you're listening to the audio. So, you have a movie of how we got this whiteboard result. That's pretty cool." (A306, 40:26)

One issue that was raised is the purpose behind the choice of graphical media. If precise information or easy sharing is needed, digital formats may be better. If convenience of communication is needed, hand-drawn graphics such as sketches, can meet these needs:

> "If it's a group effort, and ideas happen in the flow of discussion, I think it [the e-whiteboard] is quicker, which means better because you need to get ideas down quickly. [But] if I'm coming up with my own diagram while sitting in front of my computer, then I would rather spend the time to get it looking really good." (A306, 40:6)

Sketches are reported to be a good visual tool for turning mental models into physical reality:

> "For example, let's assume senior management has said 'there is a huge problem here, we need you to work on this, and get back to us with your suggested solutions'. I will do the work and then call a meeting. To support my explanation, I'll probably draw pictures on a whiteboard to support the visualisation that I have for the solution or problem. So, sketching is again a tool that I use to manifest visualisation into physical reality." (A802, 71:2)

4.3.3.2 Different Levels of Abstraction Accommodate Different Viewing Strategies

The representations which were observed have distinct levels of abstraction (earlier Figure 4.9). Numbers are the most abstract symbol and contain the least detail. To interpret numbers, graphs and charts are needed. Infographics are more complex when they combine texts, number, and forms. To reduce the cognition load and increase the chance of a picture making sense, organising them in a meaningful way in an infographic is a promising option. Icons have the lowest cognition load and contain much less detail. Photographs are the most direct static representations of the real world, and videos are the dynamic sections which contains time flow or cognitive flow, so they contain the highest amount of detail while at the same time consuming the highest cognition load.

In terms of visuals, the distinct levels of abstraction may lead to inefficient communication. Sketches are often quick to draw and abstract, but they need more interaction between the senders and the receivers assisted by other communication tools such as verbal communication or script. As described above, visuals cannot perform the communication tasks by themselves. They need to be complemented, supplemented, and facilitated.

Gestalt laws, based on our perception ability, accept that the whole is different from the sum of its part. Some of the laws, i.e. the law of nearness, familiarity, can be used to interpret and evaluate graphics. They are not only the ways people perceive visuals, but also the ways that people build their new knowledge:

> "Knowledge is about making sense of facts by stringing things together. So, I can make information connected and create a synthesis of ideas that is bigger than the individual." (A302, 10:1)

When working with complex situations, a common way was to disassemble the situation into pieces, solve them one by one, and then assemble the individual solutions into the whole. Visuals can help with this process. In the words of one participant:

> "Each of those pieces helps everybody to get a sense of what's going on. When dividing and organising things, pictures are a very useful tool." (A601, 54:5)

KV often incorporates relationships, comparison and categorisation. This is important to help the receivers understand and clarify the messages. One participant valued the structure of a mind-mapping technique as a key factor to understand what is important:

> "It helps me understand the relationships between various parts of things, and it helps with sequencing I think. So, it helps me to work out the important things to do. Before, I would think everything had to be done." (A601, 57:7)

Diagrams can depict the relationships between different concepts when sharing knowledge. This is important for complex concepts as noted by one participant:

> "Sometimes I need to be able to communicate very complex legal concepts to a client. We're often communicating these complex concepts in diagram form. For example, we've got a whiteboard, we grab pens and we draw the relationships in a diagram." (A701, 60:7)

In a nutshell, three media have been found used to support KV, and four relationships between knowledge and its representations have been confirmed from the research data. Levels of abstraction also contribute to knowledge sharing.

4.3.4 Four Situations where Visuals Fail at Knowledge Sharing

Visuals are not a tool that fits every situation. People's preferences, the shortcomings of visuals, the skills needed to create visuals and other factors need to be considered. This section discusses why some participants cannot take advantage of visual representations, Table 4.4.

Table 4.4: Four Reasons Why Visuals Fail at Knowledge Sharing

Category	Factor
Availability	• Other options to choose from as communication tools • Participants did not know how to apply visuals • Not wanting to communicate in visuals • Budgets discourage the exploitation of visuals • A discouraging culture hinders knowledge sharing with visuals
Effort Required	• Skills needed to create visuals hinder the use of KV for knowledge sharing
Time Required	• Longer time is needed if specific KV skills not available
Accuracy	• Possible misunderstandings from visual communication • Inability to interpret visuals • Inability to encode messages into visuals • Ease of getting lost

4.3.4.1 Availability

Lack of availability of tools and specific skills, for a variety of reasons, are blocks to successful employment of KV.

Other Options to Choose from as Communication Tools.

Some participants were very good at speaking and writing in scripts, and so preferred talking and writing. They would exploit their strengths first and try to avoid their weaknesses:

> "That [graphic] needs a lot of work to produce. I can talk pretty fast, so I can communicate a lot of ideas in words quickly." (A306, 38:2)

Participants did not Know how to Apply Visuals

Some participants felt that visual representations are not relevant to their jobs, so they did not know how to create visuals. They have the tendency to choose what they are good at and try to avoid the tools they are not skilled with:

> "I just don't know how to do it, although it's relevant to what I'm doing now. As usual, I'm working with datasets that I couldn't possibly retain in my head so they sit in the computer and in my role to interpret that information. So, I'm not trying to recall information in my brain but rather I pull information from the database and process it using a statistical computer tool." (A304, 23:11)

People with different mind-sets used different languages. Lateralisation was noticed during the research as one participant illustrated two types of individuals in his team: left-brain/right brain, meaning technical/artistic:

> "My left-brain people use more technical language and more technical practice. My right-brain people use more emotional language and less technical drawings, graphics, but more artistic graphics." (A1801, 97:20)

Not Wanting to Communicate in Visuals

Some participants preferred numbers, scripts and logical thinking rather than graphics and visual thinking. Accountants paid more attention to formulas and key ratios, and searched relationships between a range of factors in their accounting statements. Balance sheets, mainly in the form of tables, offer a snapshot of a company's financial condition by comparing assets with the sum of liabilities and net assets. One such participant said:

> "I don't personally mind-map, and I have tried a few times. But I'm a list person rather than a mind-map person. I find personal stuff I can mind-map but only outside of my work environment." (A1202, 76:7)

One participant was good at verbal communication so does not use visuals:

> "Yeah, when we do proposals for clients to explain our services, we quite often try to explain how we link to their organisation. I'm really good at explaining that way and I've never been good at putting that into a picture." (A1202, 76:9)

Some others did not like to draw or believed they were no good at it. They considered such drawing, either in a simple sketch or in a simple diagram on a whiteboard, as an artistic skill that is based on good intuition about layouts, colours, fonts, and key points. One participant pointed out:

> "Hearing that someone is an artist is very intimidating for people who don't think they are artists and they often have to expose a lack of skills." (A101, 1:18)

Budgets Discourage the Exploitation of Visuals.

Sometime budgetary constraints are a barrier to the use of visuals in knowledge sharing. People may lack the finances to buy a whiteboard or mind-mapping software:

> "I know there are many advanced technological things we could use, but we are constrained by the budget." (B103, 101:23)

A Discouraging Culture Hinders Knowledge Sharing with Visuals

If the culture is not supportive, everyone in the business will stop sharing, no matter whether with visuals or not. It was noticed how some of the participant organisations had whiteboards in their meeting rooms, but these were either hardly used or in some cases never used.

One participant perceived that petty competition between some business units was resulting in less sharing and collaboration:

> "Here people worry about protecting their reputation or what they perceive to be their power. Too many people forget they are actually part of somebody else's business, and should be providing a service to that business. So, a lot of people want to protect their own bad ideas regardless of any other promising ideas that may help projects for the better." (A802, 71:13).

4.3.4.2 Effort Required

Effort is needed to create and read visuals. For some people sometimes, the effort needed are simply too great and hinder the use of KV.

Skills Needed to Create Visuals Hinder the Use of KV for Knowledge Sharing

Visual techniques need specific skills, especially to create rich pictures and superior quality graphics. Even making a simple image on a computer requires specialist skill:

> [on being shown a graphic] "Wow, that would require lot of skills to create in PowerPoint, Word, or whatever program you used [Adobe Illustrator]. Yeah exactly, not a lot of us have access to Illustrator. But PowerPoint should not be so bad for creating a picture like this." (B101, 228:7)

Sometimes it is difficult for individuals to create their own images, so they need to ask help from others:

> "I've got a really good PA (personal assistant) and I can sit down with her and say, 'This is what I'm thinking about', and she can actually put into pictures for me. So, we work really well together." (A1202, 72:10)

Some projects needed a team to contribute to individual parts with specific expertise:

> "Someone like myself will come up with the concept, another person builds the model-the equations that make it work, and then I come up with the design for how we will graphically represent this. Then, somebody else writes the code…It's a team effort. "(A302, 12:8)

4.3.4.3 Time Required

Longer time is needed if specific KV skills are not available

Creating visuals is time consuming if one lacks the skill. As reported by one participant, who can speak quickly, but if asked him to draw a diagram that would take longer time.

> "That needs a lot of work to produce. The final thing that frustrated me is that visual communication. That [graphic] needs a lot of work to produce. I can talk fast, so I can communicate a lot of ideas in words quickly. If I had to draw a diagram on a computer, it would take forever to do a good graphic." (A306, 38:2)

4.3.4.3 Accuracy

The accuracy of the transferred knowledge can be reduced by several factors. Since visual representations encapsulate content within themselves, it can lead to misunderstanding. The raw ability to interpret visuals and to encode messages into visuals also calls for high levels of accuracy.

Possible Misunderstanding from Visual Communication.

Some visuals, for example rich pictures, are hard to use in communication. Also, sometimes verbal language speaks more clearly than pictures. One participant commented:

> "If I communicate with you verbally and you don't have the understanding, I can talk it through with you until you get the

> understanding. If we have a picture, I can interpret the picture in my way, you interpret the picture in your way, and it still might be a different sense of interpretation." (A1201, 71:5)

(Rightly or wrongly) this participant believed that his repeated clarification would finally reach its goal, while arguing that a visual format might lead to individual understanding thus less accuracy.

The sketch shown in Figure 4.25 exposes some of the inherent quality issues that arise when a poor visual representation is presented by the knowledge sender. A participant, when he was presented with this picture, was not able to figure out where to start, what it was for, and how to use it. It brings confusion rather than organisation of messages. Firstly, this visual representation is not self-illustrated and needed to be supported by other representations-a verbal explanation. Secondly, the starting point needed to be clarified to get the knowledge receiver on the right track. Finally, the content illustrated did not accurately correspond to its knowledge source, making it necessary to guess what the visual representations are trying to convey.

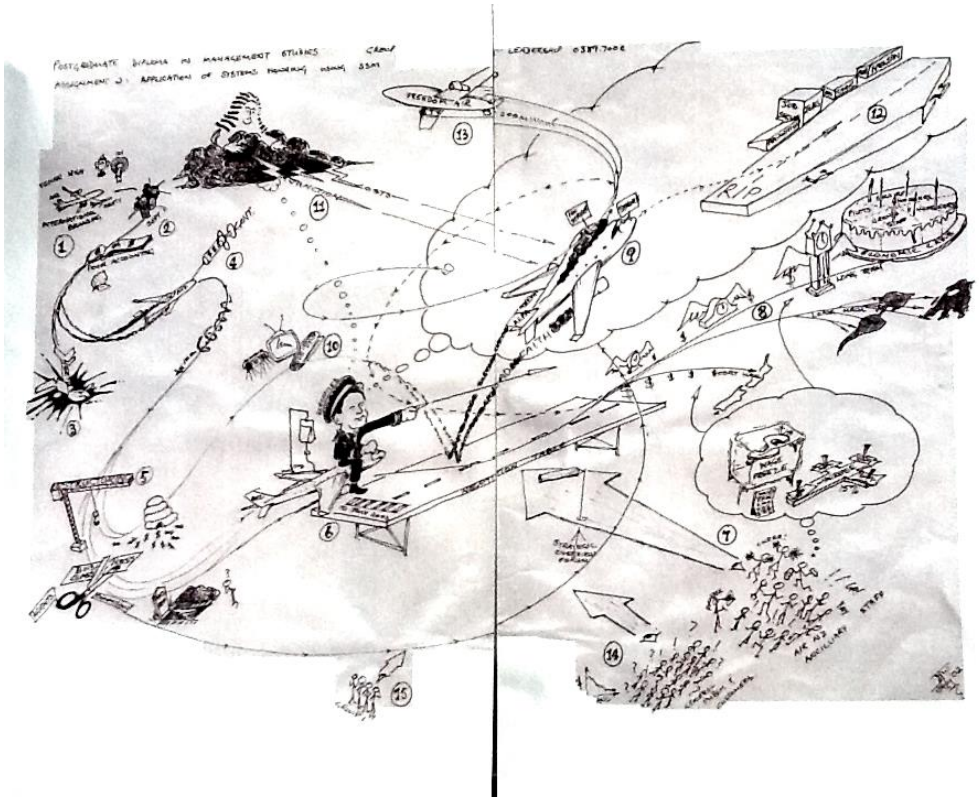

Figure 4.25: Unsuccessful Illustration due to Unclear Organisation

Source: Participant (A101, 6:1)

Inability to Interpret Visuals

The ability to understand the pictures, either during production or interpretation, is critical and should be considered when visuals are being used:

> "If you put this [graphic] in front of someone who didn't know a lot about business, it might not make a lot sense to them. But for example, if they had a strong knowledge of gardening, a different flower-type of image that's relevant for them they would understand." (A1201, 66:4)

Inability to Encode Messages into Visuals.

The skills needed to encode messages require expertise. Experts may not need visual representations to facilitate their communication as they have the knowledge and are better able to find ways to express it. As was stated by a scientist participant:

> "It doesn't really matter what tool I use as long as I get the image in front of me. Then I can be objective and I can work with the image once it's established. It can be a drawing, a 3-D model, a sketch on a piece of paper or a whiteboard. The tool doesn't really matter." (A802, 71:10)

Users with less knowledge may (or may not) need a reference system to guide them to explore the knowledge. It all depends on the individual:

> "You may know some low-level users that are quite confident with using visuals because they either have a natural ability to use the visuals or because they don't have the same perceptions of what they do as someone else." (A802, 71:5)

Ease of Getting Lost

To condense information into a graphic normally means that relationships, categories, and concepts are encapsulated into a structured drawing that can easily distract and otherwise lose people:

> "I think mind-mapping is complicated. Taking a mind-map and interpreting it is quite complicated. I can recall one time that I was using mind-mapping on a whiteboard for a group discussion. But it was difficult to end up with branches because you've got lots of branches, so it got really messy very quickly. (A306, 40:7)

4.3.5 Five Ways that Tacit Knowledge Sharing is Supported using Visualisation

4.3.5.1 A Picture is Worth a Thousand Words in Knowledge Sharing

According to the participants, visual representations are helpful for knowledge sharing for three main reasons, Figure 4.26: they can reduce the time devoted to knowledge sharing, they can increase the accuracy that facilitates knowledge sharing, and they can reduce the effort that is devoted to knowledge sharing.

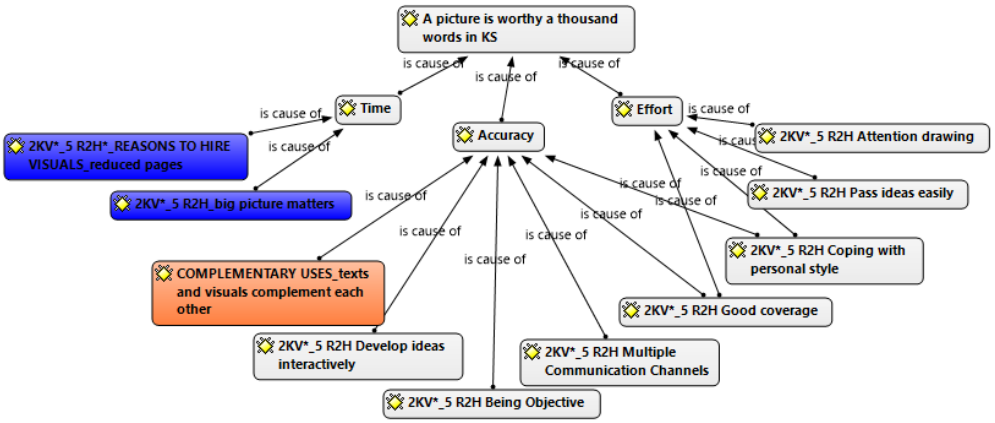

Figure 4.26: A Picture is Worth a Thousand Words, Generated by this Research

Visual Representations Can Reduce the Time Devoted to Knowledge Sharing

Condensing Information onto one Page

Visual representations can condense information into a single page and readers can scan the page rather than reading the scripts to rebuild the connections within their own heads:

> "You can scan across the whole idea with 1 sheet of paper in front of you. If you have 4 or 5 pages of text, you've got to flip back and forth and try to build up the picture in your head." (A306, 40:3)

Visual representation can also serve as a quick reference when people need to come back to it:

> "[This map] is quicker for them to absorb, and they can keep it as a quick reference. This is the best way. So quick and easy." (A306, 40:4)

This point is important for both the senders and the receivers. Knowledge senders need a compact place to hook their knowledge onto, while knowledge receivers need to to be able to grasp key information and connections without spending a lot of time.

Reducing Time by Providing the Big Picture

Visual representations give the big picture to guide readers and provide a higher level of information. Although big pictures of things are not real pictures, they facilitate understanding of the context and provide a higher perspective from which to view the subject under discussion. From this viewpoint, big pictures can be understood as mental pictures. In the words of one participant:

> "The big picture in terms of understanding context is important. And your involvement might be a small part of it, but if you know what the big picture is, you understand it at a high level. Like a map, it helps you in terms of direction and time. The company's vision is one example of the big picture." (A1201, 73:3)

Visuals were reported to be important to help see how things fit together:

> "So, I make notes, but I like to draw sketches, sometimes I draw a little flow chart, sketches to see how things fit together." (A303, 18:11)

Visual Representations Can Increase the Accuracy that Facilitates Knowledge Sharing

Accuracy is important in TK sharing and visual representations can: complement text; provide multiple communication channels; evolve ideas; be objective and valid; and, provide good coverage of the key points: Enhanced communication in the knowledge sharing process is achieved by a combination of several types of knowledge representations. This increases the chance of the receiver understanding the knowledge that is being passed in the representation.

> "I think at [the addition of visuals to verbal communication] makes the text much easier to understand, because this situation is about geography, places and space, and maps, so it's really hard to do it without [visuals]". (A303, 16:10)

Complement Text - Complementation

In terms of the complementary dance between knowledge and its visual representations, it was reported that people can learn and share their knowledge via visual representations:

> "Yeah, a couple of examples. Typically, you've got a textbook for a subject that has graphics in it. I personally like that because I have found that I think more creatively looking at the graphics than reading the words. So that's one kind of element. The other element is a practical one. If I have a series of pictures, or a video, to watch it tells me how to do something. I will probably find myself able to simulate the knowledge and successfully complete the task more quickly having that sort of 'you need to do this, then do that' information. Just like having a recipe. So, I think both in terms of the practical application of things and the sparking of my own imagination, creativity. How can I use this in my job? I think the graphical presentations are very, very powerful." (A302, 12:14)

Also, the more knowledge people have, the better representations they may produce since they gain the ability to explain their knowledge more easily. This process may contain multiple stages:

> "Sometimes if I visualise a solution and it doesn't quite solve a problem, I'll do a sketch, you know, to work out perhaps a better visualisation to show to you. These two processes go hand in hand. While I'm visualising, I will be sketching because you have to start somewhere with a solution and then develop them out of nothing to a variety of action solutions, sometimes that's a multi-stage process. (A802, 71:12)

In terms of the complementary dance between knowledge and its different knowledge representations, it was reported that people can learn and share their knowledge best when different knowledge visual representations are utilised. Communicating with clients is challenging for architects. They need to understand what the clients truly need to provide a satisfactory service. Verbal, script, and graphical communication all have their own shortcomings, so architects employ all three to get the complementary benefits.

As one architect participant reported:

> "Yep, …all three, verbal, script, and graphics. With a verbal communication channel, you can explain the original design idea. With a script, you get to record it for a file. Or we can combine that [digital] document with some graphics. As the clients explain what they want,

> we will put that into our own words, and our graphics will show how we have interpreted what we believe the client has said." (A1801, 91:8).

Another example concerns an infographic that was used by a participant organisation to promote a passive house concept to the market:

> "We did this [infographic] for a display stand at a home show so a lot of these were produced for that. Just diagrams showing and explaining what works, but again at the home show when we had this, we actually had people on the stand explaining to people passing by exactly what this about." (A1701, 94:14)

What is displayed with such a complementary communication approach depends on who is receiving the knowledge:

> "It depends on what you're talking about. For example, if I was talking about what's happening in a fishing industry, I would want to emphasise the specific industry. So, I would choose pictures of shell fish or a particular species of fish just to emphasise the point." (A1201, 73:16)

Scientists often put their findings and knowledge into publications, so the combination of graphics and texts make their sharing of knowledge more efficient and effective:

> "All of the graphics in the paper need to complement the text only for the purpose of explaining what was done. Because a picture tells a thousand words, graphics allow the readers to quickly assimilate the information you're trying to explain in the text, so supports the text and the text supports the graphics. Only rarely are graphics used to justify the text as evidence to show what we say in the paper is true. What we say in the paper is supported here with evidence, because as scientists, our work will be peer-reviewed, so we need to justify what we say. The graphics are a good way to present technical information." (A304, 21:6)

In this sense, the complementation of text and visuals provides more options for readers to choose from, thus making them more accurate and time efficient. It might even be possible to discern enough information just from the visual so that there is little further need to read the accompanying text:

> "If you only look at this figure and maybe a couple of tables, you probably don't need to read the rest of the paper, the text, because it explains everything like it is a self-contained diagram." (A401, 42:3)

Provide Multiple Channels of Communication-Redundancy

Sometimes being complementary is not enough for knowledge sharing, being redundant to guarantee the success of communication is more important. For the lawyers, they need to provide the accurate illustration to describe the situations and solutions which often come with complex concepts and relationships. Choosing the visual tools to get one more channel was a solution to their needs. Visual representation in this case provided a chance to clarify and confirm what the senders intended to share which can increase the accuracy of communication.

Participants thought multiple channels of communication ensured the likelihood of getting an idea across. The participants tended to rely on verbal communication plus efficient visuals that provide quick and straightforward information. In short, working with what may be considered redundant channels helps guarantee that sender knowledge is passed to the receiver:

> "Well, the saying is a picture is worth a thousand words, isn't it? And when I have to explain very complex legal concepts and relationships, I can easily lose people. Even when I'm choosing my words very carefully, I sometimes can't be sure even when people are nodding their heads whether they understand correctly what I'm saying. If I run a parallel diagram which illustrates graphically what I'm saying, I've got two forms of communication at once, haven't I? And if there's some form of consistency between my verbal communication and the diagram, by and large I have a better chance of my client asking me a question." (A701, 60:1)

Evolve Ideas

The interaction between knowledge and its visual representation can help to develop the exploration and identification of TK and thus enable a better representation of the knowledge taxonomy.

This is a two-way approach-going from the user to the representation and back from the representation to the user:

> "Because the visualisations represent the development of your thinking process you know it's a two-way street. You visualise something because you want to work on a solution, but because life goes on, you won't always remember it. So, you want to capture that particular idea, because sometimes ideas for solutions can be so subtle, that if you don't

> remember they are gone. So, I put them on the wall, I think that's a great idea, I draw them." (A802, 71:19)

Ideas were frequently reported to be like flashes in the brain that are soon gone. So, putting ideas into a reminder whether in a form of sticky notes or just a few key words on the whiteboards, it will be easier to come back to that idea:

> "And some of the best ideas are intuitive…you just get a flash, right? And you write it down because if you don't capture it, it's gone. You can revisit the same idea over lunch." (A802, 71:36)

This participant extended,

> "My whiteboards are always full. Some of the ideas stay there for a long time until the project is completed, and a lot of ideas I sketch up there, so while I'm working I look at them. My mind will work on them which is normal. You start to configure a better way or change some part of the idea, you know." (A802, 71:18)

This iteration process captures and draws out ideas before they are gone, allowing them to be examined later from different perspectives, and possibly integrating them with newer ideas.

Be Objective and Valid

Visual representations that include a great deal of information can easily distract from the main purpose. However, visual representations that are used with a system of rules are more precise and unambiguous than natural languages. In this sense, they are closer to a programming language in their communication ability.

A pure script can lead to misunderstanding:

> "Our industry is trying to sell ideas. If you explain to them verbally and put that in a script, they can misunderstand what you're saying." (A1801, 97:2)

On the other hand, a visual such as a sketch is abstract and easily misunderstood. Consequently, it is important for the visual to supplement the other communication approach.

As one architect participant explained:

> "If we just do a sketch, and then scan and email it, a client will imagine something from the sketch. What they imagine could be different from

> what we need them to [imagine]. Being able to talk about the sketch verbally or in a script, that is another half of your ability." (A1701, 94:7)

Visuals allow the knowledge holders to shift their perspectives to that of the recipient. In this way, knowledge holders can free themselves from the bias of their ego and stand in the shoes of the receivers, thereby encouraging better communication:

> "PowerPoint is great because you can show something to other people and ask for suggestions for refinement before you do the final presentation. This is also good because sometimes it's difficult to be objective [about your own work]." (A802, 71:31)

Looking at the same object from multiple perspectives can also improve validity. As one participant reported:

> "Because when you look at something, you look at the verbal side of it, you look at the script side of it, you can look at the graphical side of it, you can mount them together." (A1801, 97:10)

Provide good coverage of the key points

Visual representations can generate and retain ideas. Brainstorming was reported to be a practical way to generate ideas, referring mostly to TK:

> "I think that's probably the best general technique to employ because everyone can write down on a sticky note. It's great because it captures the ideas as they come out. You know if you capture an idea and throw it up on a wall, then you can look at it and revise it. You can make a decision about that particular idea a bit further down the line when things are a bit more developed. So, you can decide whether to park an idea because the essential thing about using sticky notes on the wall is that they make it difficult to miss ideas that come out." (A802, 71:37)

For geographical information especially, visuals complement the text with straightforward (map) forms of contextual information:

> "I think it makes the text much easier to understand, because this [situation] is about geography, about places and space. (A303, 16:10)

Visual Representations Can Reduce the Effort devoted to Knowledge Sharing

Visual representations can attract attention, pass ideas more easily, and simplify and meet people's sharing preferences, thus reduce the effort that will be devoted into knowledge sharing.

Attract Attention

As part of the tacit knowing process, attracting the receiver's attention gives the opportunity to access further perception. One scientist participant believed that adding visuals, signs and illustrations into his reports, made it interesting and appealing, and this could help engage his readers' attention:

> "[On this photo] I draw their attention to what is hazardous. Here there's the danger of the cliffs, a shore here that's rocky. So, I make 3-4 points in my text about it. To me the sky cover doesn't matter, facts of grass and sand don't matter. It's a whole lot of things ultimately interesting that I'm telling through the picture. (A303, 16:5)

In some situations where people have extreme emotions, drawing attention can facilitate communication and bring unexpected outcomes. When people are experiencing extreme emotions during a debate it can be difficult for them to think rationally and focus on specific topics. During a mediation session, a participant found that asking clients to draw a group diagram to show their standpoints and proposals, helped the group think together and achieve a rational outcome:

> "One of those things that I think is quite exciting happened in a meeting room. There were five people in the room and they all kind of hated and were focused on fighting each other. Then together we started putting some words, lines, and diagrams on a board, and then I started turning toward that. After a while they started pointing to it, they started drawing their points, which became a meeting which worked… very worthwhile for the people in the room. (A601, 54:3)

The visual representations became the focus and the reference object. By attracting the attention of the receivers, the effectiveness of the meeting improved and the effort needed was reduced.

Easy Transferring of Ideas

A superior quality picture helps communicate ideas easily. For example, traffic signs by the roadside show conditions and either allow or prohibit specific actions. One participant used the example of traffic signs to state the advantage of a good picture:

> "If you draw a stop sign everyone knows what it means. Most people if they see the sign, are going to stop." (A1201, 66:8)

Graphics also seem to be an easy language to help scientists communicate in their publications. Although they use the texts in the main body, they accepted the importance of the graphics:

> "…But graphics help to illustrate the points [of the text] and bring out the key concepts ideally." (A302, 10:4)

Some participants thought graphics can overtake words to help readers retain the information.

> "There is a lot of information in a picture like this… If I just used words, by tomorrow they would forget; with the picture, they will probably remember for a month." (A303, 16:12)

Due to its abstractness, visual representation can illustrate the points and bring out the key concepts easily which then reduces the effort needed to understand the ideas.

Simplification

Sometimes people just need brief information rather than detailed information. Visual representations can fulfil this role and provide a big picture of the messages.:

> "It would take a long time to verbally describe what is in this whole picture but I can give you a simplified version. Otherwise people may think, 'Okay, what's going on here?' So, it depends on how much information needs to be passed between you and others, if it's too much to talk about to someone, you need it to be simplified, to get the initial dialogue going." (A504, 53:13)

When the recipients want to know more, they can find it either by exploring the relationships within the visual representations or by reverting to another communication channel, such as verbal.

Meeting People's Sharing Preferences

People's preferences can be critical to sharing knowledge:

> "Some people really like tables, because it's very precise and it can contain lots of details. Other people think [a table is] really boring and they like photographs, which retain the relationships and patterns." (A302, 12:3)

It is reported that most people prefer visuals rather than text or tables:

> "…You can look at a diagram, an exploded pie or a small bar chart. Although you can see the same numbers appearing in a table, it doesn't have same effect." (A504, 53:2)

If people's preferences are met with KV, the effort needed to be devoted to knowledge sharing can be reduced.

In summary, visual representations can reduce the time, can increase the accuracy, and can reduce the effort expended sharing knowledge.

4.3.5.2 Factors to Consider when Employing Knowledge Visualisation for Tacit Knowledge Sharing

Three factors were noticed when considering employing KV for TK sharing: appropriateness, group size, and personal learning styles.

Appropriateness

Appropriateness refers to the aptness of the KV chosen for meeting the specific demands and purposes of TK sharing. As one participant stated, it is vital to choose the appropriate images for the communication purpose:

> "You do have to be selective on what you use. In this particular project, a staff member took measurements once a month for a year, and they took nearly a thousand pictures while they were doing it. I looked at these photos and so I can see the changes taking place. I was analysing that in my head and writing about it. But in the report, we only used 32 pictures out of the thousand. So, you do have to be selective-pictures by themselves without narrative are ultimately seriously useful." (A303, 18:22)

The architect participants extensively employ visual language as their main working communication tool because it is efficient for communicating design

concepts. 2-D drawings are used to pass the design of a building to the builders and clients:

> "Architects use visual language as their main communication language…Our job is communicating the concept. Communicating in that [visual] way, fantastic." (A1801, 86:7)

To show that the application of consistent stress does not always lead to a consistent ecosystem response, this participant used three graphs to show different conditions. The graphs and accompanying the text tell a clear story of what the author wanted to say, Figure 4.27.

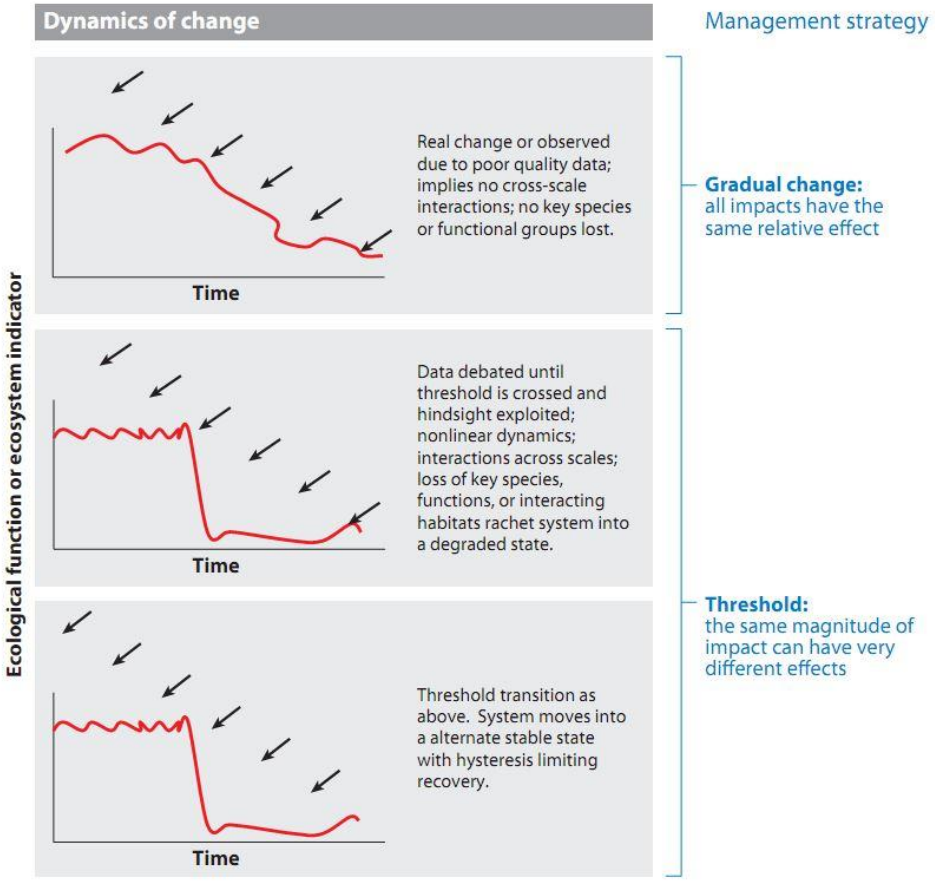

Figure 4.27: Graphs Illustrate a Story in a Scientific Publication

Source: Participant (A302, 16:1)

The participant explained why he did not combine the three graphs into one:

> "If you have three lines in a graph you tend to see the whole thing in ones and the differences between the lines becomes a little bit lost. Here what we wanted to do is use the diagram to tell a story. And we want that story to illustrate this progressive change… how we are perceiving

> changes in the environment and what is the implications of that change for how we should think about managing it." (A302, 12:7)

As was discussed earlier, different industries have different definitions of knowledge, so they have different thinking styles and KV preferences:

> "I think personally some people, mathematicians tend to think in numbers; biologists, ecologists, and teachers often tend to think in diagrams. If I was writing a paper for a science audience, I might include that but not that. But if I try to communicate what this means to a client, businessmen, or public, children, I would try to use diagrams." (A305, 35:1)

It is necessary to be careful about what technique you select to share knowledge. The form needs to serve the purpose:

> "Yeah sometimes, and therefore you align your communication ability to either express what you need to express, to clarify what you need to clarify. Some pictures are good, and get it quite clearly expressed. Other times you have to add some extra explanation to what you are presenting." (A1201, 70:12)

When it comes to terminology, the knowledge sender needs to select the appropriate way to present his ideas:

> "Technical people can read this [report] OK. But a member of the public would find it pretty hard to understand…it will more difficult for them when it comes to the terminology. So, if you want to take the same story to the public, you have to present it in an unusual way." (A303, 18:16)

Group Size

Ideas are accelerated during group discussions, as this participant reported:

> "You can spark ideas in a group that will have everybody thinking." (A306, 40:12)

However, group size was reported to be a factor in the decision to employ visuals. For small groups, it is easy to get people focused, while for large groups, people are easily distracted so an interesting picture may help the audience concentrate. As one participant reflected:

> "When I'm communicating with a small audience I don't feel the need to use images. For a larger audience, in a presentation hall say, I will use pictures and words to emphasise what I'm talking about. You might

> put one or two pictures up that people can all look at, and you can talk to that. That captures their attention." (A1201, 73:7)

Personal Learning Styles

Although visuals seem promising for knowledge sharing and communication, not everyone prefers visual communication; it depends on their individual learning style:

> "Even when I was in high school I could often picture a page of text and reproduce it. You know, like when I was in the exam. It didn't last long, like no more than a week but I knew I had the ability to remember how something looks. So, I guess, the fact is pictures really appeal to me. (B103, 101:8)

According to one participant, it is fortunate that a large proportion of the population prefers to use visuals for TK sharing:

> "You know when you look at the population for the types of learning styles, if I remember what was said from the course, there are about maybe 40-50% of people who would be visual, 10-20% auditory, and the rest kind of kinetic, learn by doing themselves. I don't know if the proportions are right, but at least the visual is the highest group. And auditory is the least, [there are] not so many of them." (B103, 112:20)

If the learners prefer a visual learning style they can benefit from the help of visuals:

> "I think if, I know sort to relate it a while coz I'm a visual learner, so I think may be the person's learning style might be the more of the deciding factor as to whether it works. (B103, 112:14)

Different people have varied preferences for visuals. From the perspective of being qualitative or quantitative, some kinds of preferences reflect the participant's thinking style: positivist or interpretivist:

> "Some people really like tables, because it's very precise and it can contain lots of details. Other people think it's really boring and they like photographs, which retain the relationships and patterns." (A302, 10:3)

It was also expressed that those people who like tables and precise information are much more logical than those who like photographs and patterns:

> "I think personally some people, mathematicians tend to think in numbers; biologists, ecologists, and teachers often tend to think in diagrams. There are different ways-kind of left brain, right brain approaches to thinking." (A305, 35:1)

Some participants were found to prefer a linguistic style over another visual thinking style and chose the tool that was a good fit with their preference:

> "I am not skilled in mind-mapping or diagramming; therefore, I choose not to use them. I am not sure if my preference for an evaluation sheet is because I am not trained in it, or because my preferred learning style is more of a verbal linguistic style than a visual one." (B107, 268:4)

This viewpoint was echoed by another participant:

> "That depends on how people best understand. Maybe a mathematician can look at a stack of numbers, and in their minds, they see the patterns. I'm not capable of doing that, so I need a graphic to understand it." (A305, 35:2)

To sum up, appropriateness, group size, and personal learning styles are the three main factors identified from the research data which need to be considered when considering employing KV for TK sharing.

4.3.5.3 Tacit Knowledge Sharing using Visuals

As visuals can help an individual build their knowledge from others' knowledge, it is important they have the visualisation skills and the required expertise at the same time:

> "…but anything that you do requires both sets of skills. You know any action that you take, you must visualise it first. So, if you do some kind of extreme sport, or if you do martial arts, you should visualise what you're going to do, and perfect the form of it before you go through and do it. And then your body should follow the visualisation. Every time you fail it's because you haven't visualised clearly enough. In martial arts practice, imagination is the key to unlocking the secrets." (A802, 71:54)

An individual can draw a sketch to show what he wants to share, but to guarantee the receivers get the right message, it is better to clarify this message with follow-up communication:

> "If we just do a sketch, and then scan and email it, a client will imagine something from the sketch. What they imagine could be different from what we need them to [imagine]. Being able to talk about the sketch verbally or in a script, that is another half of your ability." (A1701, 94:7)

For unleashing the power of the inside knowledge repository, KV seems to be more powerful than pure verbal communication, or at least shows that there are more options to choose.

It is About the Right Message

TK sharing is about sharing the right messages with others, no matter which tools or techniques are used. Although one participant thought it important to speak in the right language. more specifically, he explained how even then TK cannot always be readily shared:

> "Lots of knowledge you can't share with others. I agree. In this industry, you can explain how... Yeah, it's hard to explain that one. The artistic person can explain it to me because I'm artistic, but the technical person has difficulty to explain to me because I'm not technical. So, I've got to really concentrate on how to help the technical person explain the idea in terms that the artistic person fully understands." (A1801, 97:22).

From the perspective of the two involved parties, knowledge senders have more options to encode their messages than the options the receivers have to decode the same messages. From the interviews and observations, it was seen that senders can choose speaking, demonstration, drawing and writing to encode their knowledge by their mouths, bodies and hands, while the receivers capture the encoded messages by listening with their ears, registering physical movements, and seeing visual signs and texts with their eyes. The knowledge senders have the initiative to choose the way to encode their knowledge. As the owners of knowledge, the senders need to decide which message can be encoded and the way how it can be passed through.

Knowledge receivers are not totally passive during knowledge communication. Because the effective strategy for the senders is to stand in the shoes of the receivers, feedback from the receivers will be critical in TK sharing. The receivers can focus on the visual representations, seek clarification, and then confirm the messages.

Overall, with the facilitation of KV, TK sharing is all about sharing the right messages from the senders to the receivers.

Visuals Help Similar Minds During Tacit Knowledge Sharing

TK sharing is easier if the senders and receivers share something in common, i.e. possess at least in part a shared *knowledge repository*. This may contain prior knowledge, culture, or expertise:

> "A builder, he would understand that, you would understand that, the engineers understand that...Probably you would need to explain to us how you're thinking. Different graphics for different people with different life experiences." (A1801, 97:21)

To communicate with people who are not familiar with technical terms, speaking in non-technical language is required. As was reported by an architect participant:

> "We don't use technical terms. We actually use non-technical terms [with our clients]." (A1801, 97:25)

Sometimes when a knowledge holder encodes his knowledge into a diagram, he assumes that the receivers have the required basic knowledge:

> "I generally assume that [I'm] not going to give people a complete analysis who don't know anything about that subject. The contents tend to try to attract people with common interests and you need to assume a basic level of knowledge you can build a diagram on." (A504, 53:51)

This point is critical to understanding the importance of prior knowledge in in TK sharing.

Multi-Media and Graphical Formats Facilitate Tacit Knowledge Sharing

Multi-media and graphical formats were observed to facilitate tacit knowledge sharing. Organisation A8 had some bottleneck issues with one of their airplane models to a particular country. With its fast take-off and landing ability, it was very good for skydiving but has also been modified as different models for a variety of tasks: agricultural spraying, freight, and aerial survey. A potential client expressed his interest for a model that could integrate these functions as he preferred to buy one model which can do multiple tasks. A8's challenge was:

> "…to provide a solution for a multi-role aircraft that could be changed between several different roles as quickly as possible with a minimum downtime." (A802, 71:24)

Individual experts in their respective fields, were selected to contribute to a meeting where they discussed this key task:

> "Everyone was putting forward suggestions, and the only means we had to provide visualisation was basically pieces of paper on the wall and some whiteboards, Figure 4.28. Because they've done agriculture configurations in the past, the company owners said that's the path they wanted to head towards. But we had to facilitate manifesting a solution, using that general idea as a base." (A802, 71:33)

Figure 4.28: Decision making visuals at Organisation A8

Source: Participant (A801, 65:8)

Most of the management team, preferred an option they had experience with, which involved use of connectors that were difficult to machine, install and disassemble. However, one of their engineers began drawing a solution, Figure 4.29. that called upon a mental model he had been thinking about for several days:

> "I already had a visualisation in my head of how it could work, so I just started drawing a sketch. Because I knew the meeting was coming, and knew the design requirement, I had a little time to think and prepare my diagram. By the time of the meeting I already had the solution visually so I just drew that on the whiteboard. This basically became the solution we followed." (A802, 70:6)

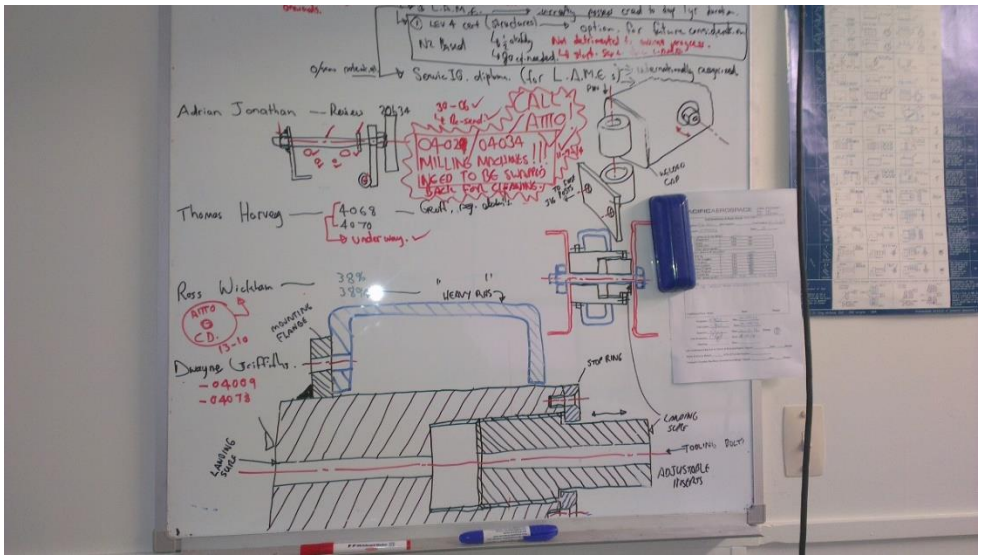

Figure 4.29: The Completed Tacit Knowledge Diagram

Source: Participant (A802, 257:1)

Multi-Stage Tacit Knowledge Exploitation with Visuals

The above situation also illustrates an example of multi-stage TK exploitation. The engineer's ability to share TK came about from having several years of experience in the field as well as the ability to think visually in his mind. He had familiarity with various connector types, so possessed knowledge, either in tacit or explicit form, of basic engineering mechanisms, their problems and solutions. When a new solution was called for, prior solutions would be referred to and integrated into the situation:

> "Throughout my working life there have been many, many engineering situations where I needed to create a solution for basic problems. So, I know engineering mechanisms and connections; there is a limited range of standard connections that you can draw on. Sometimes you need to create a new connection, depending on what you want the connection to do or on the situation." (A802, 71:22)

To exploit his TK, this participant felt that he had a natural ability to refine a concept through multiple stages: beginning with vague ideas, imagining it in different situations, trying to sketch it out, and finally refining it into a proper solution.

> "It doesn't happen by itself. I just have the ability to refine the process, to clarify and to target the clarification. If I have an idea in my head I think, 'Okay, generate it, that's a great idea', but that's not good enough to provide a solution to the problem. Then I go through the stages. I

> refine that idea in my head, and then a lot of visualisation will be explored in that process." (A802, 71:11)

If the problem is big and complicated, it is necessary to decompose it into smaller units and try to sort those out one by one:

> "I have a lot of projects in my work that start to get complicated when I consider how many other parts that particular thing is connected to. If I apply a solution to one part it may create problems for all the other parts connected to it. That's why I have to start visualising a web, where I have one part in the centre and if I have created a solution for another part then I visualise that other part going into its correct place. [Nowadays] I always pick up if this going to be a problem with other parts. Sometimes I miss, but I am usually correct, because I spend some time [on it]." (A802, 71:28)

Deconstruction of a large project at A8 is illustrated in Figure 4.30.

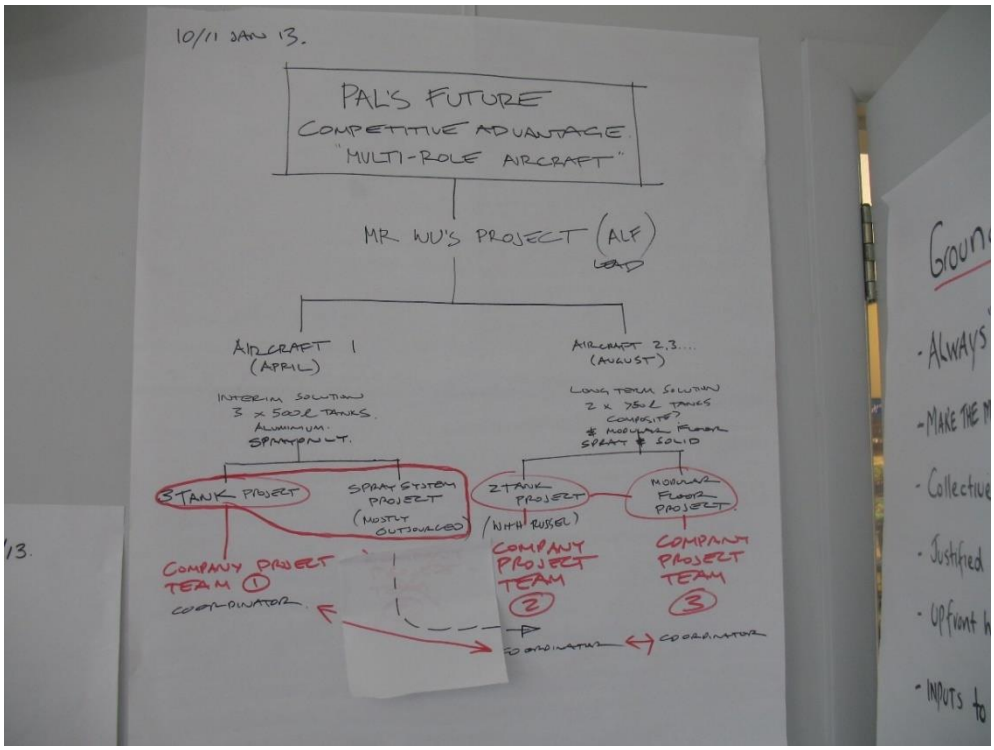

Figure 4.30: Project Structure Observed at Organisation A8

Source: Participant (A801, 65:1)

The process of refining ideas into solutions is iterative rather than linear, which may result in many solution alternatives.

Sketching helps with this process as it interacts with the mental activities:

> "Okay, this is a better solution so I warp up into the initial idea, and capture that before it's gone, then create a better one. By the time I finish the sketch, I've already developed four versions of the ideas, and gotten rid of 3 of them, because version 4 overcomes all the problems that version 1, 2, and 3 had." (A802, 71:72)

Visual representations are thought to be helpful to generate and develop ideas during the problem-solving process:

> "Sometimes if I visualise a solution and it doesn't quite solve a problem, I'll do a sketch, you know to work out perhaps a better visualisation. While I'm visualising I'll be sketching because the solutions developed have to start somewhere and then be developed into a variety of action solutions. Sometimes that's a multi-stage process." (A802, 71:12)

Critical Factors for Exploiting and Sharing Tacit Knowledge

Several factors were observed to be critical for successfully exploiting and sharing TK: the ability to use visuals; the ability to turn off mental visualisation; objectivity; and, positive culture.

Ability to Use Visuals

As reported earlier in several places, a person's ability to use visuals is one of the critical factors when one is seeking to exploit TK. The organisation A8 engineer's ability to turn his problems over to his imagination and finally into drawings to share with others:

> "It doesn't happen by itself. I just have the ability to refine the process, to clarify and to target the clarification. If I have an idea in my head I think, "Okay, generate it, that's a great idea", but that's not good enough to provide a solution to the problem. Then I go through the stages. I refine that idea down in my head, and then a lot of visualisation will be explored in that process." (A802, 71:11)

With the help of visuals, it is possible to help build knowledge, or TK, but one cannot always rely on visual tools to accelerate the process. Learners need to grow naturally:

> "They need to grow up at their own pace. You cannot force them to grow fast." (A1801, 91:17)

Ability to Turn Off Mental Visualisation

Once the solution has been reached, it is reported to be helpful to turn the divergent process of brainstorming or mind-mapping off, and concentrate on what has been chosen:

> "I drop everything, and I just visualise. I stop my thinking and you know I stop the mind chatter and the unnecessary thinking. I concentrate and I pay total attention, Sometimes I have to turn everything off, I have to go someplace quiet with no external distractions." (A802, 71:29)

One participant emphasised the importance of meditation techniques to help shut off the 'mind chatter' and concentrate on what is being undertaken. He suggested this technique can help people become more aware of their knowledge:

> "You know there are various organisations that practise mediation techniques, where for 10 or 20 minutes, you just practise being silent and self-observing. People become a lot more aware of themselves. If all your attention is out there, 'Blah Blah Blah' over everywhere, you don't have the ability to turn that off and to become clear and focused in your attention whole-heartedly on what you're doing. Your results are going to reflect that also." (A802, 71:56)

Objectivity

This reflective participant also reported how knowledge representations can help one to be more objective and overcome one's personal bias:

> "If you have the ability to put them [knowledge representations] up and be objective, you know hold them at a distance, look at it like somebody else drew it, or look at it like others do, then you don't have the personal involvement where the ego says 'That's my idea' and you become stuck on that version because 'it's my idea'. I think it's essential for my own learning." (A802, 71:73)

Positive Culture

A positive culture is one in which people can speak freely and be listened to. This enables direct and quick communication and collaboration:

> "The thing is, it is not normal now for people to have their suggestions listened to and their complaints listened to. It is all about ego." (A802, 71:26)

This participant thought the culture had fallen into petty competitions between people who are not encouraged to share their ideas. To try to change the culture, A8 employed a consultant team on design thinking.

> "You know, basically they are saying if your team cooperates on the problems you will have a lot more success, which to me is logical, and should be happening all the time, but it's not actually our reality." (A802, 71:27)

The consultant team employed by A8 provided a list of Ground Rules in the meeting room where everyone could see them, Figure 4.31.

These encouraged knowledge sharing in several ways:

1) The rules asked to be open and honest, share what they have, and justify what they assume. All these rules create an open and friendly environment for people to share what they have, encourage the participants to contribute their ideas to the group discussion.
2) The rules ask people to put themselves in the sense of the group rather than the individuals by encouraging them to say "We" rather than "I". This can encourage more group collaboration and avoid self-defence. This is helpful for knowledge sharing.
3) The rules encourage cross-boundary collaboration by asking participants to use their collective wisdom and cross the functional team. This is very helpful for the big companies which have more hierarchy and less motivation to innovation/creativity because of the tacit cultures in the organisation.
4) The rules encourage participants to sketch their ideas down onto the whiteboards rather than keep talking which can clarify the group ideas and help the further discussion.

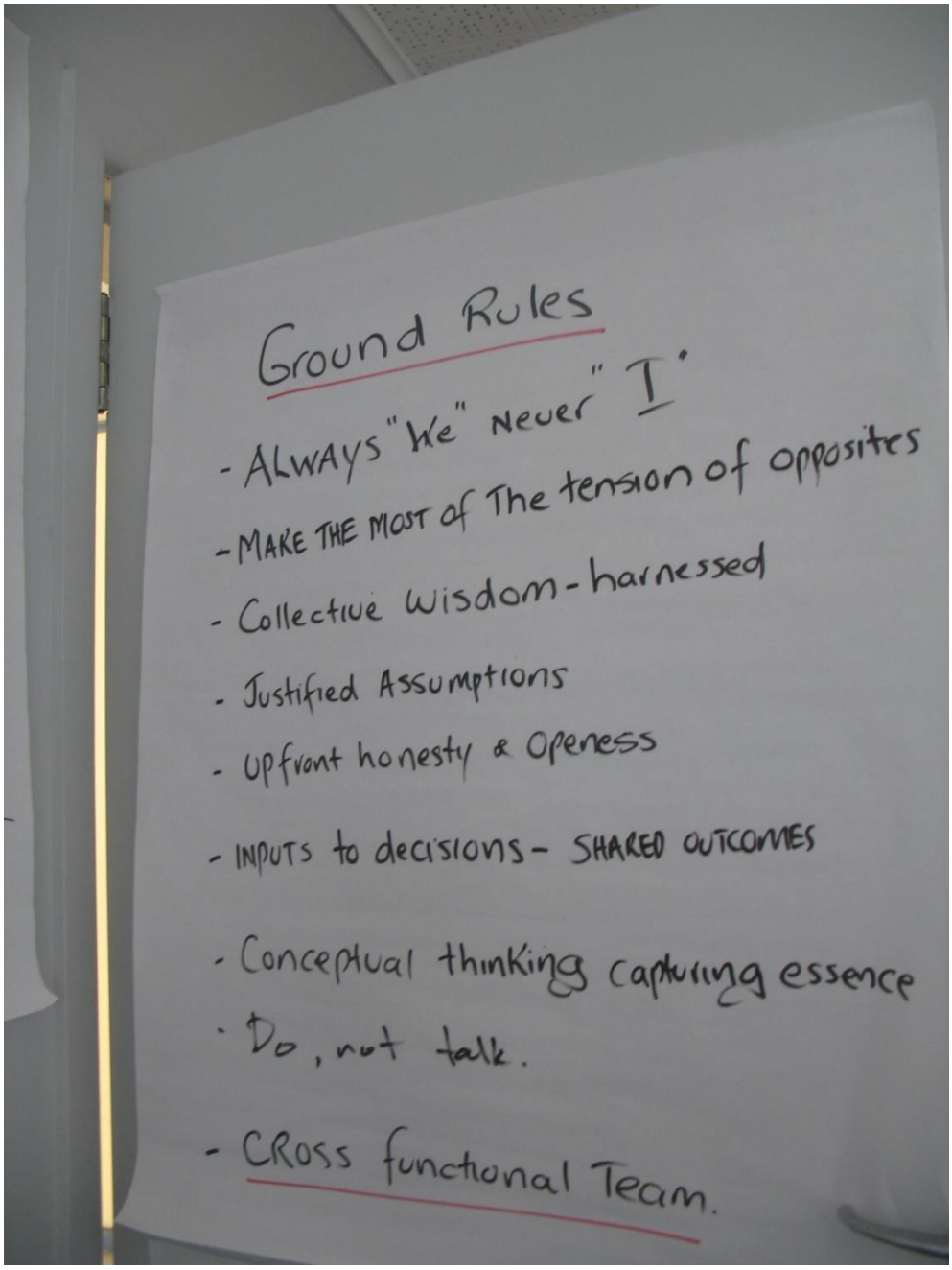

Figure 4.31: Meetings Ground Rules at Organisation A8

Source: Participant (A801, 65:6)

On the other hand, the individual's willingness to engage is what really counts:

> "Behind discipline it's willpower. That's the driver, the willingness. So that's the seed, everything else grows from that. If your level of willingness is very high, there's a very high chance that you will achieve what you want to achieve." (A802, 71:64)

It was reported that, since the consultant team employed by organisation A8 departed, the culture is back to what it was and the whiteboard in the meeting room is no longer used:

> "They have gone back to their old habits." (A802, 71:48)

4.3.5.4 More Knowledge Visualisation Means Creativity and Innovation

As mentioned above, graphical design consultants were employed by organisation A8 to help design teams solve their problems. The facilitators used design thinking and the tools of design integration to guide the teams through a sequence of communication activities in which challenges and opportunities were addressed, Figure 4.32.

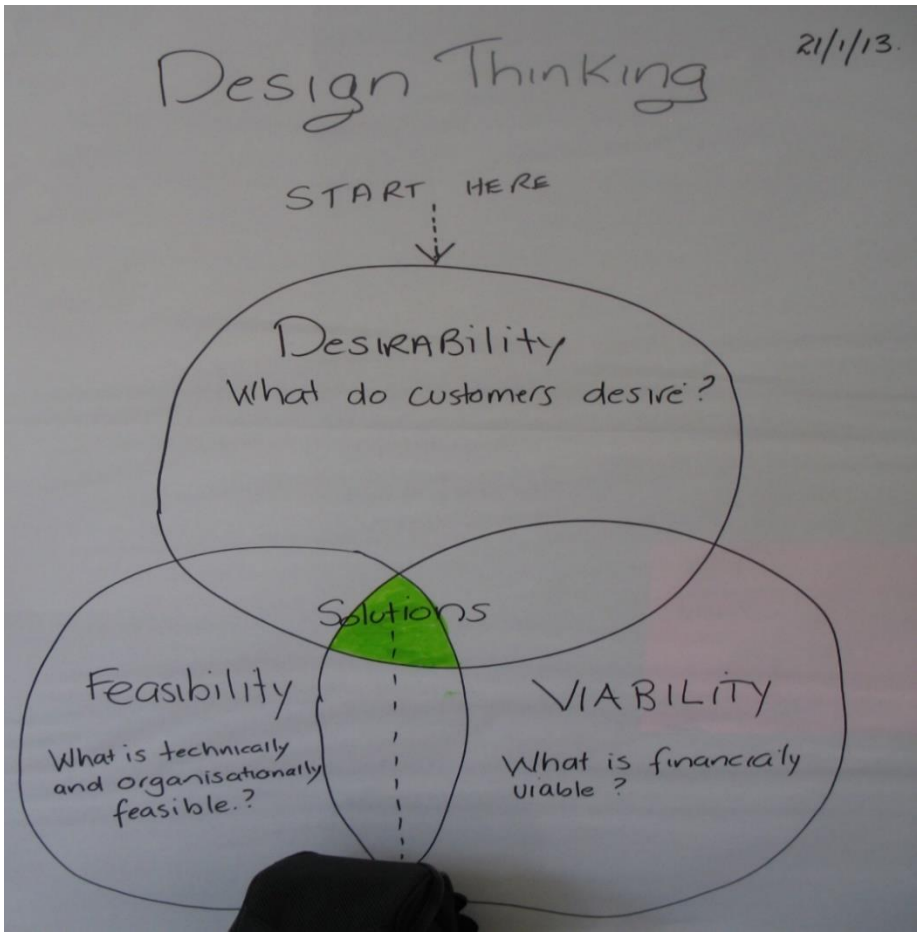

Figure 4.32: An Approach to Design Thinking

Source: Participant (A801, 267:1)

The design thinking tools were proposed to integrate the individual creativity with team/organisational innovation. Here, 'Design thinking' is referring to the methods

and processes for investigating ill-defined problems, acquiring information, analysing knowledge, and positing solutions in the design and planning fields.

The facilitators were observed to integrate conversations with visual techniques and media. They would typically gather a group of people and begin by clarifying the topic, then starting a conversation, putting the key points onto sticky notes, organising the notes into themes, and then discussing all the points until finally they reached an agreement on solutions. One example is shown in Figure 4.33, in which the coach is using sticky notes to differentiate ideas, classify the information into distinct categories, and form a big picture.

Figure 4.33: Differentiating Ideas with Sticky Notes

From the team perspective, visuals were observed to help people examine things from different perspectives, thus facilitating innovation:

To sum up, KV tools and techniques can help teams solve their problems, and innovate with creative solutions in a way that people can move out of their comfort zones, encourage more conversations and bring out fresh ideas.

4.3.5.5 Knowledge Visualisation Helps Novices Grow into Experts

When used properly, KV can help novices become more experts because KV provides one more channel of communication and saves on the effort required to interpret the received messages.

Visuals can Reduce Cognitive Effort

From the perspective of the learner, less cognitive investment means more chances for synthesis and reflection, and more chances to transmit knowledge. This is especially important when the knowledge carrier is needs to be quick and efficient:

> "When presenting I always try to use as many pictures as possible, and write down as few words as possible. Then I explain my pictures, because I think if we can present an image graphically, the messages get much more easily assimilated by the audience in the brief time you have for a presentation." (A304, 21:4)

Explicit and tacit knowledge can be extracted from the printed form quickly with the help of visuals. When EK in documents is backed by TK from the sender, on integration it will become the explicit and tacit knowledge of the receiver. In this sense, visuals help to build TK by passing the messages quickly and briefly, reducing the required workload:

> "You are going to extract the information very quickly. Particularly in papers like this, which is a synthesis or a review kind of paper, the graphics help strategically so you are not faced with 10 pages of text." (A302, 12:13)

Visuals can Help Interpret data

Numbers and statistical results especially, are often very difficult for people to digest. On the other hand, graphs when used simultaneously to display trends and relationships, etc. facilitate the perception and synthesis process:

> "When we work with the data, you can't explain that in words. I can't explain in text form every point in this plot. A graph does that instantly. The readers look at that and they can see the curves, they can see immediately the trend. There is no way you can explain that easily using text." (A304, 21:5)

Visuals can Reduce the Volume of Material

Reducing the page count provides greater opportunity to reveal the key points but does not necessarily mean that less effort is devoted to the material.

A good example of this is the use of mind-mapping, which was used by a participant in a speaking club:

> "In a mind-map, yeah, that's a good question. I found that I can get more onto one single page. In traditional notes, that may run to 3 or 4 pages to get the same information down. If you can find yourself on a single page with a mind-map, the outside of the page is to me like a frame of a picture. It gave me anyway, that sense of boundary." (B103, 101:12)

Visuals just Need a Glance

One participant thought a single diagram is worth several pages of text:

> "And just having people able to see it, to get the big picture, is much better with a diagram than with words because it would be 3-4 pages of text but only one sheet of paper to get the same information. You can scan across the whole idea with a single sheet of paper in front of you." (A306, 38:5)

Graphics used in this way can provide short-term information and thus help to overcome the limitations of our working memory. This is especially important for people who need to think and act quickly, such as when giving a speech.

Visuals can Make Complexity Simple

Breakings a visual into smaller pieces to focus on, then reassembling them to make the picture whole again, is consistent with a system thinking approach. According to one participant:

> "There is always the issue that people tend to lump everything into a problem which is so big. The solution is breaking it into pieces, and working on the [separate] solutions. "Each of those pieces helps everybody to get a sense of what's going on. When dividing and organising things, pictures are a very useful tool." (A601, 54:5)

Visuals can Facilitate Tacit Knowledge Building

Visuals provide an interesting way to increase the awareness and attention that are so essential to TK building:

> "Because lots of people knew where they were, they just didn't know there could be anything different. They were unaware of their normal behaviour, their norms. So, by giving them graphical forms, they can quickly get [to see] what the differences are like. So first, show them where they are, show them where they could be, and then help them get from where they are to where they want to be." (A101, 2:2)

Visuals can help stimulate the process to complete those practical tasks which seem to be full of TK. It was reported that visual representations can provide a recipe to follow which will make the tasks much easier.

> "If I have a series of pictures, or a video, to watch…I will probably find myself able to simulate the knowledge and successfully complete the task more quickly having that sort of 'you need to do this, then do that' information. Just like having a recipe." (A302, 12:14)

The interaction of inner perception and physical movement is reported to increase the understanding of verbal communication and this interesting finding was highlighted by two participants, who noted how the act of making textual notes while also listening helps them to learn:

> "To learn, I found I often take a lot of notes if I'm listening to something. I maybe never use them [the notes] again. Does it waste time? Some people learn quite a lot by listening, other people listen and they make notes. It doesn't really matter whether you keep the notes or not. Sometimes you do when they are useful again but it's really just the action of making the notes that cements the knowledge in your mind." (A303, 18:15)

Echoed by another participant:

> "The visualisation of the written notes helps you retain what actually has been spoken. So even if I've taken the same session many times, I will take notes without even looking at the notes again. I, for some reason, process the information a lot clearer. The commentary, the lecturer, whatever it was that has been given." (A601, 60:13)

To summarise, this section exposes how a picture is worth a thousand words in knowledge sharing, generates factors to consider when employing KV for knowledge sharing. Then a summary of TK sharing with visuals is presented before shedding a light on creativity and innovation. At last how visuals can help novices grow into experts.

4.4 Chapter Summary

This chapter has presented the main findings that were obtained from analysis of the collected data. Direct quotations from the in-depth case studies were used to support them.

These findings were sorted into themes to respond to the research questions, regarding how visuals can be used to share explicit and tacit knowledge. The key points of the findings are:

- Perceptions of what constitutes EK, and TK, vary. In particular, differences were found to exist within the different industries that formed part of this study. Architects prioritise and stress their experiences during KM, while scientists pay more attention to information conversion and the justification of facts
- TK is shareable without needing to be converted into EK first. However, multiple communication channels and multiple media need to be utilised, including stories, metaphors, and visual representations
- KV can help to share explicit and TK by offering channels of communication which, when compared with corresponding non-visual forms, reduce the effort required to interpret the messages being received.

Chapter 5 : Discussion

This chapter compares relevant literature with the research findings, to describe what was confirmed, extended and challenged

5.1 Introduction

This chapter is presented in line with Figure 5.1. It begins with a discussion of knowledge and tacit knowledge (TK) sharing, before switching attention to considerations of TK sharing in combination with knowledge visualisation (KV). A chapter summary is presented at the end.

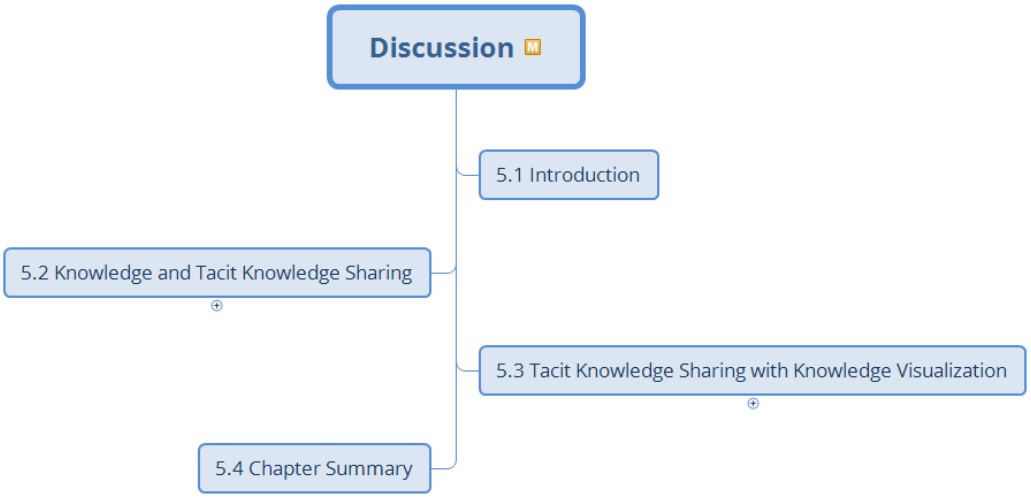

Figure 5.1: Structure of Discussions in Chapter 5

5.2 Knowledge and Tacit Knowledge Sharing

Among the debates around knowledge, TK and knowledge management (KM), this research has attempted to incorporate empirical evidence that describes real industries and their knowledge handling activities. For instance, it highlights the importance of the knowers themselves in the process of knowledge exploitation.

This study was motivated by Blair (2002) who argues that it is difficult to isolate knowledge from its owner as only individuals can have and practise knowledge. Consequently, the practitioners themselves should be managed rather than the repositories of data and information, and the knowers must be encouraged to pass their knowledge onto others through personal contact. Hence, this study explored

what **professionals** in a variety of business settings think about knowledge and how they exploit it.

Confusion arises because people do not use knowledge in a clear way, so this research was also designed to explore how people choose knowledge sharing tools; following the suggestion from Wittgenstein (1968) that if we really want to understand the meaning of a word or phrase, we should "let the use teach the meaning" (p. 471).

The discussion that follows focuses on knowledge and tacit knowledge sharing in particular, Table 5.1. It describes how a common definition of knowledge is difficult to achieve, and confirms that there are more tools available for knowledge sharing than just pure languages. It then shows how TK sharing is possible and achievable, before considering the factors which affect knowledge sharing. Differences between novices and experts are examined and the section ends by shining a light on the holistic process of KM.

Table 5.1: Discussions about Knowledge and Tacit Knowledge Sharing

<table>
<tr><td rowspan="11">5.2 Knowledge and Tacit Knowledge Sharing</td><td rowspan="2">5.2.1 A Common Definition of knowledge is Difficult to Achieve</td><td>5.2.1.1 No Clear Definition of Knowledge and Tacit Knowledge exists</td></tr>
<tr><td>5.2.1.2 Different Industries Chose Different Knowledge Definitions</td></tr>
<tr><td colspan="2">5.2.2 The Knower’s Role is Important</td></tr>
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<tr><td rowspan="3">5.2.4 Tacit Knowledge Sharing is Possible and Achievable</td><td>5.2.4.1 Reasons that Tacit Knowledge is Difficult to Express</td></tr>
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<tr><td>5.2.6.2 Sharing is Learning: The Holistic Process of Knowledge Management</td></tr>
</table>

5.2.1 A Common Definition of Knowledge is Difficult to Achieve

5.2.1.1 No Clear Definition of Knowledge and Tacit Knowledge exists

No general definition of knowledge or TK was obtained, from the literature or from the participants. Similar to the literature, those participants who had thought about a knowledge definition used a variety of terms, such as information, experience, insight, and understanding. When asked about the difference between knowledge and information they suggested terms like "useful information", "what you know", and "know how to". These responses indicate unclear understanding, and suggest that hunches are probably employed to treat knowledge as "useful" and "knowing-how". Overall, Participants mainly used three approaches to define knowledge: data-information-knowledge-wisdom (Alavi & Leidner, 2001; Blair, 2002), justified true belief (Gettier, 1963; Turri, 2012; Virtanen, 2010) and a mixture of facts, ability and perception (Davenport & Prusak, 2000; Geisler, 2008; Minsky, 1986). The term "ideas" was found to be most used as a substitute for knowledge; as was information, which is used interchangeably with knowledge. This finding corresponds to the literature in which knowledge is equated with information (Ancori, Bureth, & Cohendet, 2000; Keller & Tergan, 2005), or is taken as being multi-faceted (Kabir & Carayannis, 2013).

Irrespective of whether the participants could define the terms, they did identify the importance of knowledge and applied it without difficulty. Knowledge was considered to be a valuable asset by the scientists, and a unique experience and expertise by the architects. The participants did not spend time on justifying what knowledge is since it appears to be difficult for them, but they did use their experience, expertise, and skills to fulfil the purposes of their actions. The architects design a new building with their expertise, which can be thought of as part of their TK. In this sense, this finding confirms the mental model (Geisler, 2008; Minsky, 1986), intuition (Brockmann, 2011) or experience based view of knowledge (Liu, 2014).

Categorising knowledge into separate dimensions, such as EK and TK (Nonaka & Takeuchi, 1995), or four levels of knowledge (Brockmann, 2011), is popular with academics but was found to be not very practical. Nonaka and Takeuchi (1995) divided knowledge into explicit and tacit knowledge within their dualistic SECI (Socialisation-Externalisation-Combination- Internalisation) conversion model.

However, from the evidence of the research findings, there was hardly any justification for doing this. It seems that the participants simply do not need to divide knowledge into separate parts. This finding confirms the argument from the originator of tacit knowing, Polanyi (1962, 1966), that knowledge should be monistic as a whole. Thus, on the question of whether EK can be viewed as the indicator (Johnson, 2007) of its tacit component, this research shows that participants have difficulty separating knowledge into a dichotomy, and so it seems reasonable to accept the monistic view of knowledge. For research or communication purposes, knowledge can still be divided into more dimensions with emphasis on different perspectives.

Being articulable is not a criterion that differentiates TK from EK since those participants who rely on verbal communication still use stories and metaphors in their language. Hence, a reasonable answer to the question of whether the messages during their talks are tacit or explicit, is that participants spoke explicitly with tacit messages. On the evidence provided by the evaluators in the speaking clubs, what they were evaluating and demonstrating were mainly tacit skills. It is surprising that both the evaluators and those being evaluated learned much from the engagement, which indicates successful encoding and decoding of messages.

Once knowledge is articulated into an explicit form, such as in a product, or a book, or an expert system, it stops evolving by itself. As the participants reported, knowledge cannot evolve through itself. It is the owners who combine new inputs from the environment and generate new understanding and insights about the environment.

When digesting the EK coming from the external world, an individual needs to internalise EK again with her own TK to interpret it, and integrate much more experience to enrich it, to make the knowledge alive and mature further. This finding is meaningful as it extends the SECI model (Nonaka & Takeuchi, 2007) into a dynamic evolution. The software engineer can examine the skills involved in blending various materials, can combine them into a manual, and embody them into a product that produces tasty bread, just like a master chef did (Tsoukas, 2003). But a better bread maker, as in this case, can only be made after a new cycle of examination and externalisation is repeated, to learn more and better. During the new cycle, it is the knowledge developer who pushes the evolution. In this sense,

KM is not to separate knowledge into EK and TK, but to treat it as a whole and relate it with people.

The dualistic model also raises more problems than solutions for researchers and practitioners. For the researchers, TK can be defined as the counterpart that EK cannot express. In the dualistic model, every type of knowledge involves these two parts: one is explicit if it is accepted as being able to be expressed in language, the other is tacit which is often complemented by other forms of communication such as visual- or body language. From this, it becomes clear that the research on TK should not discuss *whether* TK can be shared, rather the emphasis should be on the question of *how*: How can TK be shared? How can knowledge communication achieve its utmost efficiency? How can visual representations facilitate knowledge communication?

From such an argument it can be perceived that many research studies investigating the tacitness (Ambrosini & Bowman, 2001; Eraut, 2000) and externalisation of TK (Busch et al., 2001) are aligned with an incorrect line of enquiry. The SECI model (Nonaka & Takeuchi, 1995) does address the "how" questions by providing a framework, but more approaches are needed to answer them from different perspectives.

The findings of this research indicate that some participants had no idea about the definition of knowledge or they had not thought about it, but that they still can use their knowledge and tacit skills well. While it might be reasonable for researchers to use a dualistic model of knowledge because they have the ability to justify the term, this model is not feasible for the average knowledge user.

5.2.1.2 Industries use Different Knowledge Definitions

The literature is enhanced by the research finding that different industries pick up their definitions of knowledge and visualisation tools based on their understanding of knowledge. Accountants in the management consultancy organisations depend heavily on numbers and data, and their role is to make sense of the data and provide feedback to management. However, more data cannot help them make better decisions. The reasons for this phenomenon were discussed by Davenport and Prusak (2000); essentially, data has no inherent meaning and too much data make it harder to identify and make sense of that data.

In contrast, an information-laden approach seems popular within the scientific community. When the scientists tried to define knowledge, they always used information as the starting point, as is reported in the literature. Chen et al (2009) tried to use logics to deduct visualisation from the DIKW (Data-Information-Knowledge -Wisdom) hierarchy, but their study was limited to computing science. In another way, architects prioritised experience and intuition as their main knowledge, since their job is to create what makes clients feel is good. Their tools are mostly based on visual representations such as drawings, models, and open houses. For architects and engineers, their skills were mostly TK which is hard to express and is practical, so they employed experience and intuition-based approaches to define, explain and understand the knowledge they have. This finding echoes that of Styhre and Gluch (2009).

The emphasis on architects extends the literature. With their five types of knowledge, Blackler (1995) and Newell et al. (2009) noticed that the more dynamic and innovative firms will concentrate on encultured knowledge if they are communication-intensive companies, such as the collaborating architects in this research. On the other hand, firms will concentrate on embrained knowledge if they are primarily dependent on individual employees' skills, experience, and expertise such as applies in the scientific organisations. It is also noticed that the definition of knowledge held by architects is very different. They believe that knowledge combines life experience and training, so it is difficult to share, but can be obtained from real work experiences. Therefore, novices need to accumulate their experience at their own pace. Thus, the tacit part of knowledge, rather than EK, is emphasised in this industry. Compared with others, architects need more collaboration and discussion, so the typical process for them is: defining a client's needs, brainstorming to get viable solutions, narrowing down to one or two solutions, then working on the solutions. The thinking style goes from divergent to convergent, which sometimes includes many divergent-convergent thinking phases within the cycle.

5.2.2 The Knowers' Role is Important

The research confirms that knowers, the individuals that possess knowledge, are critical to defining what knowledge is. From the literature, it is suggested that all knowledge can only be acquired and processed by the knowers (Heiberg Engel,

2008), or all knowledge is personal (Polanyi, 1966), or only individuals can have and exercise knowledge (Blair, 2002). The findings show that participants tend to accept knowledge as the external source of internal knowledge. Hence, the objects and subjects of the knowledge process should be stated clearly every time the term "knowledge" is used: Whose knowledge is it? From whom to whom does it go? These questions were touched upon every time the participants tried to clarify the differences between knowledge and information. Furthermore, the dominant position of individuals cannot be ignored in the knowledge process based on this information based approach. To turn information into knowledge, individuals' effort is needed and knowledge can only be held within people.

If knowledge is a mixture of objective facts and subjective perception, this further confirms that the role of the knowers is important, since only individuals can have perception and experience, and only individuals can make sense of the perceived events from the outside world, as life experience or training. Thus, any means that can facilitate perception and enrich experience should be encouraged to gain and share knowledge, thereby privileging the visual tools on which this research focuses with importance for knowledge workers.

The understanding approach to defining knowledge also confirms the importance of knowers. In this approach, understanding (knowing why) and explaining (knowing how) are the two advanced features of an individual's knowledge. An individual may have basic knowing, such as knowing what, when or where, without the ability of knowing-why or knowing-how. The understanding and explaining of knowledge needs more effort to be devoted, integrated and elevated to higher levels of one's knowledge. Without the ability of understanding or explaining, it is still possible to judge what kinds of skills are suitable. The judgement seems to be based not only on the individual's EK level, but probably from the intuition – or in other terms, the TK of the individual.

5.2.3 A Variety of Knowledge Sharing Tools

In terms of knowledge sharing or communication, there are more tools to choose from the toolbox than just natural language. However, the literature shows that many research studies that focus on knowledge conversion (Nonaka & Takeuchi, 1995) or knowledge codification (Gubbins et al., 2012; Kimble, 2013a; Schulz &

Jobe, 2001) stress the use of language. For example, it is shown that experts who work in the same domain share the same working language.

From earlier Figure 4.8 with its related findings, verbal language, physical sounds, body movement, visual language and written language are all important to carry messages between people. For TK sharing specifically, body language and visual language were found to be especially useful by the speaking club participants. Even with verbal or written language, it is still possible to integrate the tacit part of knowledge with stories, metaphors, or cases.

In general, as Cruse (2005) contended, representations cannot be separated from their internal entity as a reference. Any representation should be able to manifest itself in some way in the experience of the knowledge receivers. Language is often referring to an internal, conceptual entity (Holtgraves & Kashima, 2008, p. 75) with linguistic constituents. In this sense, language can serve as one tool to knowledge, and visual representations another tool. The importance of knowledge representations is argued here since it was observed that many organisations have whiteboards they did not use; the medium in this case cannot help with the knowledge exchange process. From this perspective, KM is the management of expertise from people, and also the environment in which people exploit and share their knowledge rather than information management or information technology infrastructure management, as suggested by (Blair, 2002).

Visual representations seem to be more promising than their verbal counterpart. Since language always displays ideas in a linear and temporal way, it always needs time and effort to encode and decode. In contrast, visual representations provide the opportunity to display in a big plane and take a quick glance to grasp what an individual seeks. Visuals can be treated as representations or depictions of knowledge inside. As was illustrated in earlier Figure 4.9, visual representations provide a vast choice when participants are choosing a tool, with which to share their knowledge. In addition to visual representations there are verbal representations, body movement, physical sounds, and so on which can be used to represent innate knowledge. This research confirms the advantages of KV over verbal tools, which echoes the literature (Bauer & Johnson-Laird, 1993; Larkin & Simon, 1987; Mento et al., 1999; John Mills, Platts, Bourne, & Richards, 2002; Novick, 2000).

Besides toolkits, this research also found that three types of media: mental, digital and physical, were employed to facilitate knowledge representations. These media were found to be especially significant; for example, when a meeting room was painted into whiteboards, which encouraged idea sharing among the employees for the challenging project they were working on, and when knowledge shared on a website benefited those who needed related information. This finding extends the KV framework proposed by Eppler and Burkhard (2007), which suggests only mental images and interactive visualisation as separate visualisation formats. This research not only noted the existence of mental and digital media, but also examined how participants used these media for knowledge sharing.

There are some loose guidelines to follow when making decisions about toolkits for different industries. As mentioned by Ferguson (1978) and confirmed by Smith (2008), drawing is the true alphabet of the engineer and much of the creative thought of the designers of our technological world is not easily reducible to words: its language is an object or a picture or a visual image in the mind" (Ferguson, 1977, p. 835). This research has confirmed that engineers and architects use such media as pre-technological drawings and technical drawings as their preferred languages to communicate.

To conclude, while participants' often confused perception of knowledge echoes the literature, some findings advance the field. From the exploration of the knowledge definition, several points can be drawn:

1) Knowledge and TK are perceived by participants to have various definitions, which echoes the literature;
2) Participants in different industries select different definitions of knowledge. The more dynamic and innovative firms will concentrate on encultured knowledge while, if they are primarily dependent on individual employees' skills, the others will pay more attention to embrained knowledge;
3) Knowledge is highly associated with its owner, so talking about knowledge cannot neglect the owners of the knowledge;
4) Domain relevant knowledge is critical for knowledge sharing but it is not easy to gain and is always time and effort consuming;
5) For communication or knowledge sharing, several tools such as body language, visual representations, or verbal language can be chosen;

6) Abstraction-complexity is an important dimension for knowledge sharing.

The next section will discuss TK sharing specifically before moving to discussion of KV in the following section. It will be confirmed from the research data that TK can be shared in multiple ways and this sharing and learning process will show a holistic picture. Differences between experts and novices will be detailed.

5.2.4 Tacit Knowledge Sharing is Possible and Achievable

TK is realised to have multi-dimensional relationships in terms of sharing and communication rather than in just a linguistic dimension. From the original definition from Polanyi (1966, 1968), TK and EK are often placed in the coordinate of being expressible or not. This research examined the multiple approaches to sharing TK and noted that TK that may be difficult to express in a natural language may still be expressible and shareable via body movements, visual representations, or physical sounds.

5.2.4.1 Reasons why Tacit Knowledge is Difficult to Express in Language

There are assorted reasons why TK fails to be reducible in language. Firstly, TK is mostly related with actions (Brockmann, 2011; Liu, 2014), and some actions are performed subconsciously without any awareness, so cannot be expressed on the level of language. For example, it would be difficult for a speaking club participant to think about all the skills she uses during a speech. However, if she had the related skills and performed those skills naturally, often without any awareness, a great speech would still be achieved. Skills require enough expertise to be identified on the awareness level, and it was found that different levels of consciousness and approach occurred when an engineer tried to exploit his TK. Since there are multiple ways to take advantage of various levels of consciousness, sometimes he needed to turn the inside chatter off and find a quiet place to concentrate on one solution.

Secondly, action skills are replete with detail. For example, when a speaking club participant placed emphasis on the word "long" during her speech, it was suggested she move her hands apart as she did so. The speed and how far the hands should be moved, and how long the hands should be kept apart were all details which were too much for the person to express in linear and temporal language. This point extends the literature by providing a new way to examine TK.

Thirdly, action skills depend on the context (Ambrosini & Bowman, 2001). As the context changes, the skills will be different during each performance. The scientist and speaker participants all reported paying attention to the audience when they were making presentations, and adjusted the skills they employed accordingly.

Fourthly, our natural language is limited or abstract in some sense which makes TK difficult to express (Ambrosini & Bowman, 2001), so if we relate TK with language ability there must be some situations we cannot describe. For example, the participants sometimes found it was useful to grab a pen or marker to write some notes onto the whiteboard or a piece of paper, or to draw a picture to depict a complex situation.

Finally, there is often not much incentive to express TK since TK is always built into the action. Moreover, TK is personal and difficult for the knowers to communicate to others (Ambrosini & Bowman, 2001). For example, Polanyi (1966), in describing the nail hitting action, argues that the purpose of the person who performs the action is to finish hitting the nails into the benches. Expressing to others how to hit a nail would be at the advanced level of communication (compared to hitting the nail itself). This was confirmed via observation of the novice speakers in the speaking clubs, whose main purpose was to improve their speaking skills rather than their sharing ability. As their speaking skills increased, their ability to articulate their speaking skills also increased. So, in this sense, TK articulation is based on expertise.

Finally, as expertise grows, articulation skills will grow due to repeated performances surfacing tacit skills from the subconscious level to the conscious level. However, even expert performers who can demonstrate their skills by actions, or through language, in general are unable to share them totally in words. This metaphor of speaking different languages is meaningful for similar situations at different knowledge levels. Experts working in the same domain might share the same working language, but when talking about the details or different directions of their expertise, sometimes it is as if they are speaking different languages.

5.2.4.2 Tacit Knowledge is shareable

This research confirms that culture is part of TK (Daft & Lengel, 1986; Sternberg et al., 2000). It was found that whereas the culture of an organisation might be difficult to articulate in words, culture did affect behaviours. It was observed that supportive companies that encourage employees to share their ideas seem to have more chance of this occurring. Otherwise, as was reported by participants from one case organisation, the employees would keep everything they know inside, leading to a phenomenon they called 'petty competition'.

TK can be shared in ways that reflect a close relationship with the process it has been built from or the knowledge source from which it is abstracted. In the speaking club case a novice can learn from observation what others manage to achieve with their speaking skills. The observer will try to remember and practice what are thought to be good skills and try to avoid what is not so good. If the learning comes via evaluation, the judgements and suggestions only work when the learners have similar experiences on that point and then it can be possible for the learner to build more skill onto previous ones. This finding corresponds to the literature (Alony et al., 2007; Gubbins et al., 2012; Liu, 2014) that holds TK sharing is not just a copy of TK: it is recreation of TK.

Another important finding of this research is that TK can be shared via language, which contradicts some literature such as Nonaka and Takeuchi (2007) who indicated TK can be shared only when it becomes explicit. Earlier research reveals that TK may be effectively converted via analogies, metaphors and stories, sometimes even with the right questions asked (Gubbins et al., 2012). The present research shows that TK or experiences can be shared in the form of stories, or a combination of verbal language with visual approaches. This finding echoes Holtgraves and Kashima (2008) who indicated that language can help share TK. Different verbs imply various kinds of causality which shows "a tendency for interpersonal verbs to imply a particular causal focus" (p. 78). Action verbs (e.g. help) are more likely to be assigned greater weight by the person performing the action than to the person who is the recipient of the action (Brown & Fish, 1983). This research did not analyse the use of verbs or other specific part of speech, but the interviews did investigate how the participants gained insights from

communication with others-which is part of the reason why participants believed that knowledge or TK can be shared via verbal communication.

Another important finding is that visual representations can gain advantages from the implicit causality in terms of TK sharing. It was found that visual representations have higher efficiency since, with just a quick glance, it is often possible to decode the relationship between different concepts. People can judge causality by looking at a series of interconnecting arcs (arrows) and nodes (states and events) (Hill & Wright, 2012).

The use of visual techniques/media in a meeting can facilitate TK sharing. Whiteboards, sticky notes, and flip charts were observed to enable the participation, thus facilitating the sharing of knowledge. One participant described how he communicates with his own mind for a better solution with the help of drawings on a whiteboard. This finding corresponds to Da Vinci's Sketches as reported by Burkhard (2005a).

Two approaches were observed among participants who deliberately wanted to keep their forms of expression tacit rather than explicit. One approach was used when it was difficult for the participant to articulate something, such as tacit skills, explicitly (the nail hitting scenario). The other approach was used when tacitness is much better than being explicit in communication, which is more of a strategic choice. People may select metaphors or stories to indicate what they mean, rather than tell their intentions straightforwardly. Detection of this phenomenon enhances the literature, as no studies were found to report such a situation. Also, it is helpful to declare that it is not necessary to focus on the articulation of TK such as Nonaka and Takeuchi (2007) did in their SECI model.

5.2.4.3 Multiple Ways to Share Tacit Knowledge

Multiple methods were found to be useful for sharing TK. This finding confirms the literature as stated by Gubbins et al. (2012) that effective TK conversion may successfully be achieved with analogies, metaphors and stories. The **visual metaphor** in earlier Figure 4.19 represents an attempt to show employees how trust affects the culture in an organisation. As can been seen from the tacit nature of culture, the visual metaphor of the thermometer served the purpose powerfully. **Analogies** were detected during the interviews when participants found it difficult

to express their opinions directly or when they tried to clarify meaning. Two approaches were found. One was seen in the use of a metaphor, such as a window, that functions as an interface that allows interactions with the other side of the world. The other involves using examples. When participants gave their viewpoints in an abstract way, they would often like to elaborate their points into an example to make it easier to understand. **Stories** are a popular form in the speaking clubs, and are thought to be an effective communication approach for speeches. It is reported that stories can gain interest, provide quick understanding and help memorize messages.

Exploiting TK can be facilitated by visuals in combination with other means. The most promising approach to exploiting TK is not to convert it into explicit form (Nonaka & Takeuchi, 2007), rather to make it acceptable to others and keep it reusable for many other followers. Visual metaphors, stories, and analogies have proven their roles in the process of TK sharing (Gubbins et al., 2012).

The multiple ways to share TK demonstrate the shortcomings of language and opens up new avenues to TK. Language itself has some limitations for TK sharing. The meaning of language not only resides in the message, but needs the active involvement of participants. Considering the communication process, in which senders and recipients are involved, illocutionary force or perlocutionary effects cannot be avoided (Holtgraves & Kashima, 2008). Holtgraves and Kashima (2008) noted that language cannot "guarantee complete and mutual understanding" (p. 74), so it is better to get help from other representations such as visual representations or other individual communication means, such as body language. From this sense, TK should not be related closely to language, and TK sharing should have broader toolkits to choose from.

One interesting point from the interviews is that TK sharing is thought to be facilitated by requesting a "leap of faith" which can correspond to the classical definition of knowledge as Justified True Beliefs (JTB) from Plato (Kimble, 2013a). It may be hard to understand TK from others, but knowledge can be acquired by simply accepting and believing in it. This is the case when the distance between the knowledge levels is very wide, say between a novice and someone who is the authority in the field. In this instance, experts can explain the details but the receivers cannot justify and decode the message, so the best receiver strategy seems

to be to accept it and wait for further exposure of clues. The research data reveals how, on one occasion, an architect participant asked his clients to trust the architect's proposal with a leap of faith.

Another interesting finding is regarding common or prior knowledge. It was observed that technical people can understand technicians while artistic people can better understand those with an artistic mind. This finding echoes Breite, Koskinen, Pihlanto, and Vanharanta (1999) and Gubbins et al. (2012) that two individuals from different 'technical' backgrounds could not speak the same language and thus had difficulties achieving the same goals.

Abstraction-complexity is used as the first dimension to categorise all the possibilities. Earlier Figure 4.8, and its related findings, demonstrate that numbers, having the highest degree of abstraction require other representations to illustrate the same scenario. This demonstrates the linear nature of numbers and scripts (Flusser, 2002). On the other hand, visuals can show more detail so are more complicated in their relationships. Due to the priority of visual information, visual representation can also be processed more quickly than can verbal directions.

Visuals are perceived to be important to knowledge building and sharing, which can be explained by Gestalt principles that have the tendency to form a whole from pieces (Nan et al., 2011). Gestalt rules, namely similarity, proximity, continuity, closure, and regularity, embrace the nature of grouping and explain how human beings perceive forms (figures or objects) instead of a collection of simple lines and curves (Nan et al., 2011). From the research findings, the most common way to work with a complex situation is to disassemble the whole into smaller parts. Once solutions to the smaller parts are achieved, the solution for the whole is easier to find. During this process, visual representations are used to maintain the big picture and make clear the connections between the parts.

Different levels of abstraction accommodate different viewing strategies, which confirms the idea of Scaife and Rogers (1996) that "abstraction of material should be appropriate to the varying demands of the task and the learner's ability" (p.206), The research findings also correspond with other literature (Massironi, 2002; Wickens et al., 2003). Sketches which are quick to draw and abstract require more

interaction between the senders and the receivers and is assisted by other tools such as verbal communications and written scripts.

5.2.5 Factors that Affect Knowledge Sharing

Three factors that affect TK sharing: conveniency, motivation and domain relevant knowledge. These factors variously include aspects of open space, interpersonal relationship, willingness, availability of facilities, and domain relevant knowledge, which can be classified into internal and external factors, and emphasise the importance of the role of the knowers. Internal factors comprise motivation and prior knowledge, while external factors comprise open space and availability of facilities.

Given enough prior knowledge and motivation to share, TK sharing can be facilitated via open space, and available facilities. In other words, if the internal factors are strong enough, positive external factors will bring positive results.

This research confirms open plan areas to be a positive factor for knowledge sharing (Appel-Meulenbroek, 2010; Filius, Jong, & Roelofs, 2000). Physical conveniency has been notified as one barrier to TK sharing (Cardinal & Hatfield, 2000; Napier & Ferris, 1993). Mahroeian and Forozia (2012) noted that domain relevant knowledge is a property of value, whereas Alony et al. (2007) noted that domain relevant knowledge is a property of knowledge shared, diversity and common knowledge. Interpersonal relationships in this research reflects trust in the literature (Alony et al., 2007; Majewska & Szulczynska, 2014). The availability of facilities echoes the higher level demands for applicable methods and practices for TK sharing (Majewska & Szulczynska, 2014).

As noted by some researchers (Gubbins et al., 2012; Reagans & McEvily, 2003), new knowledge comes from a combination of prior knowledge with new incoming information, and the knowledge sharing process becomes easier if the parties share common domain relevant knowledge (Reagans & McEvily, 2003). As was reported by the participants, domain relevant knowledge can facilitate knowledge identification and sharing. When reading a scientific publication, it is easier to have specific knowledge to understand the messages that was placed into the article by the author. But, it is also argued that prior knowledge or common knowledge is not

easy to achieve. Individuals need time to learn and those who are interacting need to actively collaborate in the building process of this common knowledge.

This research extends the literature on the three factors by standing firmly in the shoes of the knowers and classifying factors into external and internal groups. The factors proposed by the literature (Cumberland & Githens, 2012) are overlaid and the barriers uncovered by this research propose a new way to understand the phenomenon.

5.2.6 Differences between Expert and Novice Learning

Differences between novices and experts were noted and their respective ability to share knowledge in a process of learning.

5.2.6.1 Differences between Experts and Novices

The differences between experts and novices noted during this research correspond with the literature (Dalkir, 2011; Dreyfus & Dreyfus, 2005). It was found that experts can discern extra detail better than novices. This ability came about from life experiences, which take time to accumulate. Although it might seem difficult to accelerate the development of novices, if innovative ways to punctuate the surface of TK (Tsoukas, 2003) could be utilised, it might be possible to facilitate TK sharing that boosts skills acquisition and TK acquisition.

It was noted that people develop enhanced speaking skills once they can identify and judge them for themselves. This means that while an individual evaluator may know how to properly perform an action during a speech, they may still find it hard to perform the same skill themselves. That is good news for learners as they can identify what they should learn, which guides them in the right direction. However, a downside is the effect that was identified by Kruger and Dunning (1999), who showed that incompetent people tend to overestimate their competence and experts tend to underestimate their competence-erroneously assuming that what is easy for them should be easy for everyone else. This was observed in the speaking club, where new members tended to think that their speaking skills were good enough. Once they observed how people make speeches they began to realise their true competence. Thus, evaluators need to put what seems obvious into evaluative reports which can be easily grasped by others.

Calculative rationality and deliberative rationality as described by Dreyfus and Dreyfus (2005) was confirmed in this research. When an experienced engineer tries to solve a problem, he proposes his ideas, tests them, discusses them with others, and improves them. He has made himself more experienced in his field, which means he has acquired more ability to make better decisions. This points at deliberative rationality. Similarly, in the speaking clubs, the expert speakers attempt to improve by challenging themselves with more difficult speeches and evaluations. On the other hand, the novice speakers tend to follow guidance and instructions, which points at calculative rationality.

5.2.6.2 Sharing is Learning: The Holistic Process of Knowledge Management

The findings show that TK can be built with experience, which means experts spend time dwelling on the details, encountering every situation, and making every mistake, so when they come to a new problem they can transfer the experience to the new situation. This corresponds to Ray (2009), who stated that learning happens when the experience picks up more details. As discussed above, TK is thought to be difficult to acquire because it involves getting to grips with so much detail.

Practice makes perfect. At the Toastmasters club, members develop their speaking and leadership skills by participating in speeches or evaluations. A learner may start with a certain objective, trying to speak before the audience, or integrate body language successfully with the presentation. She will read manuals or articles related to her objective (i.e., reading the EK of others and having a preparation of conceptual knowledge). This finding confirms the literature (McQueen & Chen, 2010; Ray, 2009; Tsoukas, 2003) by including experiential learning and practical actions into the activities.

The ability to share knowledge is also part of the process of learning. As Dreyfus and Dreyfus (2005) showed, as expertise grows, the ability to perform a skill also develop, together with opportunities to perform the skill. Before acquiring the ability to share knowledge, expertise must be acquired. This point is confirmed by this research. Whereas a novice speaker was puzzled when she noticed that it was not appropriate to say, “Thank you” at the end of her speech, an expert speaker was able to explain why and demonstrate how to perform the related skills competently

at the same time. It is clear that the expert speaker was much more familiar with the requisite skills and possessed the ability to perform and explain them.

Overall, this research confirms that no clear definition of knowledge and TK was detected in the empirical evidence. The key role of knowers is confirmed, and more options for knowledge sharing are demonstrated. TK is shareable and can be shared via language in the form of stories, metaphors, and cases. Three factors which affect knowledge sharing correspond with the literature. These observations also pave the way for novices to develop their expertise.

5.3 Tacit Knowledge Sharing with Knowledge Visualisation

KV is a term that is commonly found in the knowledge representation literature (Eppler & Burkhard, 2007; Minhong & Jacobson, 2011; Minhong et al., 2011). While much of this literature only involves visual representations, other media are used as carriers of knowledge representation (Ababneh & Edwards, 2007). This research considered interactions between knowledge and its visual representations and techniques. It examined TK sharing with the assistance of visual tools.

The discussion that follows compares the KV findings from the previous chapter with the relevant literature, and highlights important points. Table 5.2 outlines the section structure.

Table 5.2: Tacit Knowledge Sharing with Knowledge Visualisation

5.3 Tacit Knowledge Sharing with Knowledge Visualisation	5.3.1 Tools for Knowledge Building and Sharing	
	5.3.2 Good Visualisation: Knowledge Visualisation Metrics	5.3.2.1 Effectiveness
		5.3.2.2 Efficiency
	5.3.3 The Limitations of Knowledge Visualisation	5.3.3.1 Lack of Facilities or Skills Leads to Rejection of Knowledge Visualisation
		5.3.3.2 Knowledge Visualisation does not always Reduce Effort
		5.3.3.3 Knowledge Visualisation does not always Save Time
		5.3.3.4 Knowledge Visualisation is not always Accurate
	5.3.4 Knowledge Visualisation works for Tacit Knowledge Sharing	5.3.4.1 Knowledge Visualisation Helps Rebuild Contexts to Share Tacit Knowledge
		5.3.4.2 The Act in Visualisation Helps Reflection and Tacit Knowledge Sharing
	5.3.5 Knowledge Visualisation Encourages Interactions that Facilitate Tacit Knowledge Sharing	5.3.5.1 Knowledge Visualisation Encourages Interaction Within the Individual
		5.3.5.2 Knowledge Visualisation Encourages Interaction Between Individuals

5.3.1 Tools for Knowledge Building and Sharing

The literature (Massironi, 2002; Wickens et al., 2003) suggests that different tools meet different purposes, and this was confirmed by this research. The reasons for participants to use visuals as communication tools are complex, such as being driven by communication needs, individual preferences, and availability of a specific tool.

Emails or phone conversations, which mainly concern EK or information sharing, often cannot completely satisfy communication needs, requiring meetings or round-table discussions. It was noted that, at some point or for some complex situation when a face-to-face conversation became challenging, a pen or marker would be used to draw on a piece of paper or a whiteboard, and this made the communication

much easier. This finding extends the literature by providing a new perspective to think about more options for better KM.

It was noted that visuals can be more specific than language, especially for those users who do not understand the language in use. This finding corresponds to the literature (Bauer & Johnson-Laird, 1993; Berger et al., 2013; Larkin & Simon, 1987; Novick, 2000). It is easier to identify an object as being a 'desk' by drawing it, compared to referring to it in a language not understood by everyone. Its key details, whether the legs have a round or a square section, will also be shown by the drawing. The importance of such details depends on the importance of the abstraction, which can be judged by the receivers based on the context.

This research follows the approach by Massironi (2002) and presents a tentative taxonomy of visual representations which are supported by the research data and emphasise the knowledge sharing perspective. This is based on the 'abstraction-complexity' and 'real-mental world' axes, which extends the research literature by providing an intuitive framework for researchers and practitioners.

This research also differentiates visual tools/representations and media to provide a holistic picture for all of the visual communication approaches. Eppler and Burkhard (2004) identified different KV formats but failed to justify the visual techniques and visual media. This research clarifies these aspects and thereby helps direct future research efforts.

Four relationships suggested by Kendler (2013) are confirmed by this research: redundancy, complementation, supplementation, and stage setting/context rebuilding. It was found that two or three channels of communication were employed to guarantee the success of transferring ideas. The complementation of knowledge and its visual representation includes two facets: the complementary dance between knowledge and its visual representation, and the complementary use of different knowledge representations. It is important for the visuals to be supplementary to other communication approaches. For geographical information, the visuals complemented the text with straightforward forms of providing information. This research finding also suggests that, to achieve the full potential of representations, it is necessary to work with various alternatives and to play to each one's strengths.

Even when overshadowed by people's styles and preferences, visuals can still shed light on communications. Someone may prefer numbers and verbal communication, but they will still need visual techniques to transfer their ideas quickly and precisely. It was noted that, in such cases, graphs were often used to extract useful information from the data.

For the speakers at the speaking club, it seems that not only one approach matters, but any approach which can improve speech and performance. Therefore how to combine the various communication skills with verbal skills has become a critical proficiency to learn and practise. Also, if people lack visual-making skills they may seek assistance. One accountant partcipant sought help from her personal assisant who had the required skills to generate visuals.

Bergström's (2008) communication conditions were noted in this research: over-communication, under-communication and poor communication. The situation of the lawyer and architect participants, who stressed their joint use of words and visuals in a dual-channel communication to provide redundancy, echoes the over-communication condition with anchorage (Barthes, 1981) or complementation (Kendler, 2013). To attract recipients' attention, the architect reported how he showed an infographic of an energy-saving house, and if the recipient wanted to learn more, the best way was to talk with them and gather information from them directly. This is the situation where under-communication occurs. Similarly, poor communication was often observed when the knowledge gap between the senders and the receivers was so wide that recipients lacked the ability to make sense of a situation and it becomes difficult to engage their attention.

5.3.2 Good Knowledge Visualisation: Knowledge Visualisation Metrics

This research has synthesised the factors that facilitate or hinder the knowledge process with visual representations, and classifies these factors into the two qualitative factors: effectiveness and efficiency. Although the literature (Desouza & Paquette, 2011; Ellis, 2009) examines these two factors, no research has paid attention to the field of KV. This research has shown that KV efficiency and KV effectiveness mutually improve one another. Hence, this research extends the literature by proposing the positive influence of both effectiveness and efficiency on KV quality.

5.3.2.1 Knowledge Visualisation Effectiveness

"Form follows function" is a principle first associated with modernist architectural and industrial design in the 20th century. Thus, the shape of a building or object should be primarily based upon its intended function or purpose. In this research, *effectiveness* implies that the KV 'visual' should produce the desired result (Desouza & Paquette, 2011). As the research data shows, the KV representation that is being employed by the participants can help achieve their demands and fulfil their work purposes. Considering the preference of individuals and availability of KV skills or facilities, effectiveness can be boosted if KV is appropriately employed.

5.3.2.2 Knowledge Visualisation Efficiency

All the research findings in terms of KV efficiency point to four factors: tool availability, tool accuracy, the effort needed to encode and decode, and the time consumed during the process. Here *Availability* refers to those situations when a medium is needed, when a skill to create visuals is needed, or when the expertise to encode or decode visual representations is needed. Availability has a positive effect on the efficiency of KV.

For the scientist participants, the availability of a visual medium such as Skype, which offers video chat and voice call services, was reported to reduce travel time and increase the desire to communicate between colleagues. This finding echoes the literature which suggests that physical separation makes it more difficult to share dimensions of TK (Napier & Ferris, 1993). Conversely, being in close physical proximity has a positive effect on TK sharing (Cardinal & Hatfield, 2000).

Accuracy describes the degree to which the receiver can understand what the sender tries to share. The perfect scenario occurs when the receiver completely understands the message. However, due to the losses caused by the encoding and decoding process, it can be difficult to always attain good accuracy. Participants in this study variously strove for higher accuracy by doubling up the number of channels used to share knowledge; by using complementary text messages; and by simplifying the key points:

Doubling the channels used to share knowledge. One participant was very confident in his verbal communication but he still preferred to use a drawing to

enhance his communication. In his opinion, the drawing provided him with another channel to convey his messages.

Complementary text messages. As one participant stated, graphics can help readers to quickly assimilate the written textual information.

Simplification of key points. The law of *pragnanz*, also called the law of good figure or the law of simplicity, is the central law of Gestalt psychology. Every stimulus pattern is seen in such a way that the resulting structure is as simple as possible. Evidence from this research also points in this direction. One participant used a traffic sign to illustrate how some pictures are very clear and superior to verbal communication, because they are universal and easy to perceive. For some scientists, graphics help them to reduce complicated ideas into simple graphics with key points and concepts.

Visuals are expected to reduce the amount of *Effort* that is required for senders when they encode what they wish to share with receivers of their knowledge. As suggested by Maslow's concept of the law of the instrument, otherwise known as the law of the hammer (Maslow (1966), cognitive bias can involve an overreliance on a familiar tool. Hence, knowledge senders prefer to choose the tools they are familiar with. For instance, when one lawyer tried to show the relationship between a researcher and a department, he used a marker pen to draw on his whiteboard. He likes drawing and so he is confident to using drawing tools. Other participants asserted that their lack of drawing skills, limited their choice of available visual tools. One participant was very happy she had an assistant who could draw on her behalf, while another was 'terrified' at even the thought of having to use a visual and kept away from such tools.

Visuals are also expected to reduce the amount of effort that is required for the receivers to decode what they receive from the knowledge senders. As described earlier, a clear and easy to digest picture can be worth a thousand words. Furthermore, when coming back for a reference, an organised picture is perceived to be quicker than accessing 'a pile of books'. The limitations of our working memory mean that knowledge that is organised into visual forms can reduce the effort needed that is required to digest and reflect.

The effort expended on specific tasks also depends on the coupling of personal communication style with choice of tool. A person with access to the appropriate tools has an easy job and can work efficiently.

The *Time* that is consumed during the sharing process is a critical factor affecting the choice of tool(s). A quick scan of a picture can sometimes convey the message while a book needs to be read from the first page to the last. And, while it is possible to scan a book, the relationships between the concepts it contains are not readily explicit. Graphics make the entire process much easier by linking ideas and concepts via simple arrows and curves.

To sum up, this research presents a tentative taxonomy of visual representations, and it differentiates visual tools/representations and media to provide a holistic picture for all the visual communication approaches. Thus, it extends the literature by synthesising a qualitative KV metric that proposes the positive influence of both effectiveness and efficiency on KV quality.

5.3.3 The Limitations of Knowledge Visualisation

It was found that not every KV is successful; a finding that extends the scope of the literature into the negative side of KV. KV rejection can arise from any of the four categories: availability, accuracy, effort, and time.

5.3.3.1 Lack of Knowledge Visualisation Facilities or Skills Leads to Rejection of Knowledge Visualisation

Some participants did not like or were afraid to utilise visuals, some perceived they held no relevance to their job, and others were able to rely on a better communication option. In short, KV tended to be rejected due to a perceived lack of need.

People's preferences cannot be ignored when selecting KV as the knowledge sharing approach. Armstrong, Peterson, and Rayner (2012) and Gubbins et al. (2012) commented that different learning and cognitive styles can influence behaviour and choice; some people rely more on images to learn effectively and communicate while others learn better from verbal media. Similar situations arose the present study. A manager in a science instituition was noted to heavily rely on verbal communication because he had confidence in his verbal skills. He spoke all the time

and tried to make people understand his exclusively verbal communication. A speaker in the speaking club often used mind-mapping techniques and thought of herself as a visual learner. An engineer confirmed himself as a visual learner and communicator. He liked to sketch his ideas on whiteboards and paper in order to reflect on them and use them for communication.

The availability of such facilities as video conferencing systems can restrict the use of KV due to factors related to company budgeting and culture. If a company is unable to provide the necessary financial support or a positive environment that encourages people to communicate, KV activities will be rejected.

5.3.3.2 Knowledge Visualisation does not Reduce Effort

Participants choose to utilise KV when it is perceived to reduce effort, otherwise it is likely to be rejected. For example, because a manager in a scientific institution not very proficient at creating a neat drawing on a computer, it was difficult for him to use this form of KV. Instead, he chose to utilise his verbal communication strengths, which minimised the personal effort required. Similarly, a complicated sketch generated during a meeting was easy for someone who had been present to refer to and understand, but for those anyone joining the meeting later, they would probably need to talk first to an individual who had been there, and this would increase the amount of effort needed to understand it.

5.3.3.3 Knowledge Visualisation does not always Save Time

Participants in general will not employ KV if it takes a long time to produce or apply. For the manager in the scientific institution, producing a neat drawing on a computer would take a long time, so it became natural for him to use other communication means. However, it was noted that the time consumed in utilising KV is a relative concept that is always compared with other approaches. If that same KV takes less time to use than a pure script, the KV will be given priority.

5.3.3.4 Knowledge Visualisation is not always Accurate

It was noted that sometimes KV is overly complicated by displaying relationships, connections, and elevated levels of abstraction. A lawyer decided it was better to complement verbal communication with visual communication, and a novice needed to acquire certain expertise to decode the visuals. Some visuals were difficult to follow if the audience was not familiar with the topic.

This research has provided a new holistic picture in the world of KV, which is based on an examination of the use of different media and the relationships between KV and knowledge. It was also noted that KV may fail in some circumstances.

5.3.4 Knowledge Visualisation Works for Tacit Knowledge Sharing

This research pays attention to TK sharing facilitated by visuals. The following discussion examines this topic and compares the relevant literature with the research findings.

5.3.4.1 Knowledge Visualisation Helps Rebuild Contexts to Share Tacit Knowledge

KV can be used to deliver the big picture that provides the context that is so important for assuring knowledge sharing. Although Kendler (2013) describes this as stage-setting, for this TK research context is considered to be a more appropriate term. When a participant used Google Earth™ to show the locations of pest traps installed in a valley (see earlier Figure 4.15), it was easy to comprehend where the locations were, and the density of the traps. In this case, a map rebuilt the context within which to share TK.

5.3.4.2 The Act of Visualisation Helps Reflection and Tacit Knowledge Sharing

As noted by Kinchin et al. (2008), the act of concept mapping can slow down reflection around actions that are normally automated and thereby overlooked, thus enabling access to TK. This research confirms that the act of drawing can accelerate the encoding and decoding processes, which makes TK more shareable. An argument that had arisen between two parties was observed to cease when they began to draw on a whiteboard and could understand what the other party was claiming. At the same time, those doing the drawing needed to be logical and clear of mind, which further encouraged them to stop arguing and begin thinking. When engineers faced challenging issues to upgrade their airplane they gathered in a meeting room to discuss the issues, and used sticky notes to propose workable solutions. They then compared various proposals to reach agreement. The action of drawing and reflection made it possible to combine everyone's expertise into an acceptable solution.

Visuals also facilitate multiple ways to access TK. Participant A802 reported how he visualises alternative solutions to problems in his head, and draws sketches if necessary. To share this knowledge in a meeting with his colleagues or the senior management team, he often wraps it into drawings which he judges are easy for others to understand. Thus, the key points employed are imagination, incubation, self-reflection and introspection. This finding corresponds to Brockmann's (2011) different levels and access to knowledge.

5.3.5 Knowledge Visualisation Interactions Facilitate Tacit Knowledge Sharing

5.3.5.1 Knowledge Visualisation Encourages Interaction Within the Individual

Participants reported how the ideas, which seem to come from the repository of TK, are always subtle and disappear, so sticky notes, sketches and whiteboards were used to capture them. One participant described how she created an objective representation 'outside her head', which engaged with her inside repository, and then she tried to make the objective representation better. The representation generated may be EK or not. After a few iterations, the ideas mature and finally become a proposal or a solution to a problem.

This finding indicates that TK can be accessed via a dialogue between the representation and the individual, which corresponds to Tsoukas' (2003) suggestion for gaining access to TK: new knowledge comes about not when the tacit becomes explicit, but when our skilled performance is punctuated by new ways of talking, fresh forms of interacting, and novel ways of distinguishing and connecting. In this sense, KV provides a new way to interact with the 'internal world' and explore the potential to utilise this valuable asset. As was noted by a participant who always needs to develop ideas via drawings, the objective manifestation can be viewed from other perspectives, which encourages further TK access and sharing.

5.3.5.2 Knowledge Visualisation Encourages more Interaction Between Individuals

KV encourages more interactions between individuals because it can provide a target for others to either accept or dispute. When a group had conflicts over an issue, the mediator asked them to draw on whiteboards, which then became the

focal point for discussion, and encouraged more contributions than conflict. Similarly, when a group of engineers met to find a better solution, an experienced engineer proposed a solution, which the participants then contributed to, in order to improve it.

KV can be viewed again and again, with just a quick glance, which is much easier for participants than a pure script. This finding further echoes Tsoukas' (2003) proposal for ways of punctuating TK.

5.4 Chapter Summary

This chapter has compared the literature with the research findings, to identify the contradictions and consistency. As discussed, some of its key points are:

- Participants are often not clear about the definition of knowledge and related terms, which is a similar finding to the literature. Also, different industries employ different definitions and knowledge-sharing tools. The importance of the knower's prior knowledge and of the abstract-complexity dimension is confirmed by this research.
- TK is confirmed to be shareable not only via language in the forms of stories or metaphors, but also via a combination of verbal language and visual tools. Three factors that affect TK sharing were proposed and discussed.
- Visuals, whether in the form of visual formats or visual media, can be used to share knowledge and TK in some circumstances.
- KV quality can be assessed via consideration of KV effectiveness and efficiency in combination. Here, KV efficiency points to four factors: tool availability, tool accuracy, the effort needed to encode and decode, and the time consumed during the process.
- The limitations of knowledge visualisation mean that not every visual representation will be successful; a finding that extends the scope of the literature into the negative side of KV.
- KV encourages more interactions, thus facilitates TK sharing, whether within individuals or between individuals.

Chapter 6 : Conclusions and Implications

This chapter the main contributions of this study, identifies future research directions, and describes the limitations of the research design, Figure 6.1.

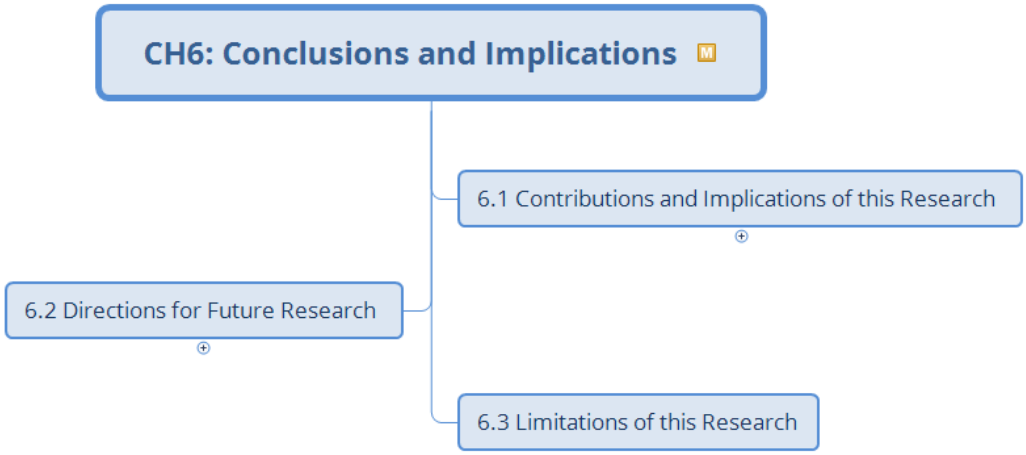

Figure 6.1: Structure of Conclusions and Implications in Chapter 6

6.1 Contributions and Implications of this Research

RQ: How can visuals facilitate the tacit knowledge sharing process?

- How do professionals share their knowledge with others, especially the tacit part?
- What kinds of visuals were employed to aid communication?
- How do people use visuals to facilitate knowledge sharing process?
- What are people's purposes of KV in terms of knowledge sharing and communication?
- How do people evaluate the effectiveness of KV in knowledge sharing?
- Why does KV sometimes fail to facilitate knowledge sharing?
- How can KV be used to facilitate TK sharing?
- How can KV help novices grow into experts?

In addressing these questions, this study makes original (academic and practitioner) contributions, which are collected into three major groupings:

1. TK can be shared via both language and visual representations,
2. The way TK sharing can be facilitated using KV tools, and
3. 3. A proposed new KV taxonomy.

6.1.1 Tacit Knowledge can be Shared both via Language and Visual Representation

The first major group of contributions concerns TK sharing.

This research confirms that TK sharing does not necessarily relate to the direct conversion from TK to EK, but that conversion can take advantage of metaphors, analogies, stories, and visual representations. This finding disputes a common view in the research literature that "only convertible TK can be shared". This finding is significant because it embraces other possibilities for making TK accessible and acceptable to recipients

Indirect conversion from TK to EK is of special significance to managers and knowledge workers who, the research shows, often have little idea about what knowledge and TK are. Rather than asking employees to document what they know, how they perform should become the priority. Moreover, as there often appears to be some element of TK that an individual cannot explain, the research also revealed how a 'leap of faith' can be utilised to increase confidence when TK cannot be expressed. In short, business people can ask for a vote of confidence from their clients when they cannot explain something clearly to them.

Three knowledge sharing enablers were detected that echoed the extant literature: conveniency, motivation and domain relevant knowledge. These enablers comprise of open space, interpersonal relationships, willingness, availability of facilities, and domain relevant knowledge. Consistent with the viewpoints of individually held knowledge, prior knowledge was confirmed to be critical for knowledge sharing. In particular, this research examines the usage of open space, which has gained little attention in the literature. Detailed data was gathered around when there is no physical boundary between the knowledge workers and they can communicate with

each other whenever they like via whiteboard/pin board, and meeting room, and so on. This data will encourage further contributions to this field.

The next contribution is the distinction that is made between participants in different industries who, because they exploit knowledge differently, used different definitions and toolkits, and choose different representations. For architects, their knowledge tends to be predominantly tacit and their representations are mainly graphical sketches and drawings. For scientists, their knowledge is more explicit and logical and their representations are mainly in script form. Such fundamental differences of knowledge and knowledge representations between industries does not appear to have been highlighted by the literature, and provides a new insight.

The next contribution came about by the researcher shifting perspective from knowledge sender to knowledge receiver. The extant knowledge sharing literature almost always focuses on the senders of knowledge from the shoes of the receivers, with the focus on the senders trying to make their TK explicit. This implies that the ability to articulate TK goes somewhat in hand with the level of sender expertise. In contrast, by 'inhabiting the shoes of the sender' this research demonstrates that visuals can reduce the amount of effort required for the receiver to decode what they are receiving from the sender. The implication for 'sender practitioners' is that, if they know how "receiver practitioners" learn and their preferred learning style (verbal, visual, etc.), they can adjust their knowledge sharing strategy to suit, and thereby assure more effective knowledge sharing. Similarly, if the learner knows that her starting point is to embrace TK, practice would become more accepting, patient and tolerant.

6.1.2 Facilitating Tacit Knowledge Sharing by Using Knowledge Visualisation Tools

This study appears to be the first to document a practical approach to examining knowledge sharing, especially involving TK sharing, by using the tools of visual representation and communication.

This research also examines the different situations in which experts and novices employ KV for TK sharing, which is thought to be useful for helping novices to become experts. The sharing of expertise has been a focal point for many years, and this research provides an approach which uses the 'power of visuals' to make TK

sharing more effective. Knowing how KV can be employed for TK sharing enables knowledge practitioners to confidently employ KV. Also, realising how other experts have been able to share their TK with novices might motivate experts and novices to re-think their current approaches and techniques.

6.1.3 Towards a Knowledge Visualisation Taxonomy

This research takes a tentative first step toward synthesising the wide variety of KV formats and media, positioning them within a space defined by the twin dimensions of 'real-mental' and 'abstract-complex'. Such a bridging of the gaps between KV and TK required that research achievements from philosophy, psychology, neuropsychology and neuroscience be combined with TK management. This focus on knowledge and TK helps to extend the research field into practice.

While several frameworks outline KV techniques, little attention has been paid specifically to TK. This research provides a new framework that examines KV formats from the perspective of TK. This wrapping of physical, mental and digital media, into a KV framework provides a new clarification of KV. The mental medium has a close relation with knowledge itself which pushes the literature to further examine this topic specifically.

For knowledge workers needing to employ a certain kind of visual technique and medium for their knowledge sharing activities, the toolbox provided by this research offers greater convenience. An individual can easily locate what is needed (refer to earlier Figure 4.9). In terms of media, each can cater for different purposes. For example, if an individual must share with many people, the digital form would be the first choice.

6.2 Directions for Future Research

Several fruitful avenues for knowledge management research arise from this study. These relate to three principal areas: KM, TK sharing, and KV.

6.2.1 Future Research in Knowledge Management

- The first suggested avenue of research is to study the way disparate industries define their knowledge base. Since the definition of knowledge is

fundamental to the choice of its representations and sharing, it is necessary to explore this topic with the aid of in-depth data.

- This research has collected data from participants in New Zealand-based organisations, without paying specific attention to their cultural environment. However, TK can be viewed, at least in part, as being the product of national culture. Tong and Mitra (2009) demonstrate that employees in Chinese manufacturing enterprises like to keep their knowledge implicit and are willing to share it informally. Hence, a potential fruitful avenue for research is to explore whether other cultures experience the same influencers of knowledge management and sharing practice.

6.2.2 Future Research in Tacit Knowledge Sharing

- Regarding TK sharing specifically, it would be helpful to explore TK sharing at differing levels of expertise. Dreyfus and Dreyfus (2005) propose that as expertise grows, the ability to perform a skill grows, and the possibility to express that skill also grows. This research gathered evidence from 'novices and experts' but did not examine intervening levels, such as advanced beginners. Experts are believed to use more intuition, hence people with different levels of expertise use different level of intuition, which may lead to different models of TK sharing, and different choices of communication tools.
- The relationship between intuition and its visual representation is judged worthy of further study. TK, expertise, and visualisation are all reported to be closely related with intuition. Although this study justified TK sharing facilitated by KV, more research is necessary to test the relationships between these three fields.

6.2.3 Future Research in Knowledge Visualisation

- As mentioned above, this research has collected data from participants in New Zealand-based organisations. However, other cultures often employ different visual representations, making it necessary to compare research findings across multi-cultural contexts.
- In today's world of big data analytics, graphical representations and sense-making are becoming very important for business communication and

innovation. Since graphical facilitation is closely related to communication via visual representations, it is necessary to examine the effects of facilitation on organisational knowledge sharing. There is currently almost no research interest in this.

- This research examined how knowledge sharing is facilitated using open spaces, whiteboards/pin boards, and meeting rooms. It was observed that open space encouraged more conversations and interactions, which facilitated (even TK) sharing. Very little research was detected that investigates the relationships between space layouts and knowledge sharing, making this a potentially fruitful avenue for future research.

6.3 Limitations of this Research

Inevitably, any study of this scope has limitations. For example, only a limited range of visual representations were observed and analysed for this research. Other forms of visual communication, such as audio-visual communication or multi-visual communication (Bergström, 2008), were not encountered. Since a broad range of visual representations are thought to contribute to the knowledge sharing process, strictly speaking it is necessary to include these 'missing' media to gain the full picture.

This study relied heavily on interviews for collecting participant perceptions. However, the nature of their TK sharing can be difficult for participants to espouse. Similarly, although observations were used to gain insights into tacit knowledge sharing practices, TK sharing in ad hoc knowledge management settings is difficult to observe. Thus, participatory action research is judged to be a useful way forward that offers increased levels of observer control.

Participant data was collected from New Zealand organisations and it was assumed that how these participants share their knowledge accurately represents the Western cultural style. It is reasonable to expect that different national cultures will employ other visual representations to share knowledge to those which were observed in this study (Holtgraves & Kashima, 2008). Observations of eastern cultures will be scheduled into further research, in part so that differences between ideographic writing and alphabetic writing (Meyer, 1991) might be observed.

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Appendices

Appendix A: Cases and Participants

Industry	Date	Participants	Data Collection Methods
Management Consultation (5)	2/4/2013	A101	interview, documentary review
	28/5/2013	A1201,1202	interview, documentary review
	29/5/2013	A1301	interview
	6/12/2016	A2001	interview
Education (2)	3/4/2013	A201	interview
	4/6/2013	A1601	interview, observation documentary review
Scientific Service (12)	12/11/2012	A301	interview, documentary review
	5/1/2013	A302	interview, documentary review
	5/3/2013	A303, A304	interview, documentary review
	5/6/2013	A305	interview, documentary review
	7/6/2013	A306	interview, documentary review
	4/7/2013	A307	interview, documentary review
	8/5/2013	A401	interview, documentary review
	19/2/2013	A501	interview, documentary review
	4/3/2013	A502	interview, documentary review
	18/3/2013	A503	interview, documentary review
	19/3/2013	A504	interview, documentary review
Law Consultation (3)	23/4/2013	A601	interview, documentary review, observation
	15/5/2013	A701, A702	interview, documentary review
Manufacturing (2)	14/2/2013	A8	documentary review observation
	6/9/2014	A802	interview, documentary review
	5/4/2013	A1001	interview, documentary review

Appendix A: Cases and Participants (Continued)

Industry	Date	Participants	Data Collection Methods
Software (2)	7/6/2013	A1401 A1402	interview, documentary review
Architecture (3)	18/6/2013	A1701	interview, documentary review, observation
	21/6/2013	A1801	interview, documentary review, observation
	8/7/2013	A1901	interview, documentary review
Speaking Club (6)	7/11/2013	B101	interview, documentary review, observation
	4/6/2013	B102	interview, documentary review, observation
	24/11/2013	B103	interview, documentary review, observation
	7/11/2013	B104	interview, documentary review, observation
	05/05/2015	B105	interview, documentary review, observation
	14/12/2013	B201	interview

Note:

1. The numbers behind each industry shows the numbers of participants;

2. The date format is dd/mm/yy.

Appendix B: Outlines of Semi-Structured Interview Questions

This outline for the semi-structured interview is for the ethical application and data collection purpose. The researcher will use this outline as a guide to interview participants. The questions will be asked from the additional questions first to the main questions with clarifications. Five topics are included as visual preference, perception and skills, experience, insight, and feedback.

Visual Preference

Main questions	Additional questions	Clarifying questions
What kind of learning style do you think you are?	Do you prefer reading books with lots of graphics? Do you think that makes the book easy to understand? Are you a left-hand user or right-hand? What kind of graphics do you prefer? Do you prefer any kind of visuals to help you learn, think or communicate in your daily job or life?	Do you learn or think with low-level graphics such as pie chart, column chart etc. which just organise information or high-level ones such as sketches, metaphors, and mind-maps etc. which interplay with your thoughts?
What do you think about mental visuals or imagination?	Do you like daydreaming, stories, or metaphors? Why do you think people use stories or metaphor to pass their ideas? Do you think they are effective?	Do you like telling stories? Do you like reading stories?

Perception and skills

Main questions	Additional questions	Clarifying questions
What kind of skill do you think needs for your current job?	What kind of job are you doing? What are your responsibilities?	
What do you think the definition of knowledge is?	Any difference between knowledge and other concepts like information or data?	
How do you facilitate your learning during work?	Do you need learn new things during your work? Do you use any tools to facilitate learning? Are they helpful?	What kind of new knowledge do you need to learn? What kind of tools do you use a lot?
How do you communicate with colleagues?	Which one do you prefer for daily communication, emails, phone call Skype, or face-to-face talk? Do you often use PPT to make a report? Do you think if it's helpful? Can you tell me an experience when you've had to acquire some complicated knowledge from another individual, and what visualization techniques you or the other person used to help in that transfer of knowledge?	Can you explain a little? Can you tell me anything else? Can you give me some examples?
What do you know about the visual tools?	Have you used any of the visual tools once before?	In which situation?

Experience on graphics

Main questions	Additional questions	Clarifying questions
What kind of knowledge visualisation techniques have you used?	Knowledge visualisation is about the use of tools and diagrams like this one(examples) that help people to communicate and structure ideas when communicating with others. Have you ever used yourself, or been in meetings where others have used tools or diagrams like this?	
What kind of graphics have you tried?	Do you think if it's proper for your job? Have you thought about other tools? Why?	Why?
How do you use graphics during your work?	For what purpose? With whom? In which situation? Or use simple or complimentary one?	Why?
What do you get from your own experience or others'?	Do you share your experience with your peers, or do your peers share their experience with you? What's the most important part do you think from experience, either yours or others'? And did you think the use of that tool helped to get the ideas across?	In which way, stories or hand-drawing? Could you please elaborate on that a bit more?

Insights on graphics

Main questions	Additional questions	Clarifying questions
Do you think visuals can help you learn faster than before?	How?	And why?
Here is a graphic. Do you think this might be useful in helping you communicate your ideas and thoughts to others in your team?		How and why?
Do you think visuals can help you communicate more efficiently than before?	How?	And why?
What's your opinion on the visual thinking and learning?	Do you think if it's helpful when you use visuals to help you yourself? Do you think if it's helpful when your team begin to use visuals? What kinds of outcome are more important for you, innovation, productivity, or learning ability? What kinds of elements do you find more important in a meaningful graphic? Big picture, distinct colours, different curves, or the combination of graphics with text? Why?	How?
When you write a report, what percent of the page count is made up of diagrams and pictures?	If hardly any, do you feel it's better to be concise with words?	How and why?

Feedback and improvement

Main questions	Additional questions	Clarifying questions
What kind of elements do you like with the graphics?	Big picture, distinct colours, different curves, or the combination of graphics with text? And why? What kind of elements do you not like with the graphics? And why?	Can you explain a little? Can you tell me anything else? Can you give me some examples?
What kind of improvements do you think we can make to make this research work better?	How and why?	
Do you have anything else to share with me?		