Computing for Knowledge Management: From Nonaka to Visualisation and Knowledge Maps

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I certify that this dissertation which I now submit for examination for the award of MSc in Computing (Knowledge Management), is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the test of my work.

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ABSTRACT

There is great confusion about what Knowledge Management really is and what contribution Computing for Knowledge Management can make. Knowledge Management itself is not always clearly understood, however, the confusion can be sorted if the underlying theory is clearly distinguished from its implementations. There also may be a specific role for computing in Knowledge Management. It is suggested that Knowledge Management technologists seek a unique strategic position for Computing in Knowledge Management, for reasons of clarity and differentiation from Information Systems. The effective transfer of knowledge is one of the main themes or core competency in Knowledge Management. This is also one of the areas where Knowledge Management technologists may find the niche for a distinct and unique contribution the field of computing can provide. This dissertation finds that Computing for Knowledge Management can be seen as the meeting of the computer sciences, cognitive psychology and sociology since this combination is fit to produce a uniquely user centric outcome. Scientists working the field of Visualisation have already created the foundations on which Knowledge Management technologists may start building. This applies particularly to its subsection of Knowledge Visualisation and by extension to Knowledge Maps. This dissertation investigates the advantages of Knowledge Management tools based on Knowledge Maps, how such a system might be implemented and what issues in terms of people, process and technology must be expected to arise. An experiment was conducted to find out about these issues. The same knowledge base content was presented to two groups of users, one group was presented with a tabular yellow pages type of knowledge map; the other was presented with a graphic knowledge map interface. Participants had to perform a search task and were given a recall test. The experiment tool recorded user activity and answers given for statistical analysis. Participation was too low to lead to any conclusions but the experiment still yielded useful results.

Key words: *Knowledge Management, Knowledge Transfer, Visualisation, Knowledge Maps, Cognitive Psychology, Human-Computer Interaction*

ACKNOWLEDGEMENTS

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1. INTRODUCTION

1.1 Background

Knowledge Management (henceforth abbreviated KM) is an organisational and therefore social issue. It is, however, not without controversy. King *et al.* (2002) elucidate on the considerable confusion regarding function and nature of KM and its technological implementations. Wilson (2002) even argues that KM is no more than Information Management and that KM systems are nothing other than Information Systems flying a different flag. Ives *et al.* (1998) claim that the principles of KM have their roots as far back as the famed Library of Alexandria. Such a claim in terms of KM is a rather two-edged sword since it can be argued that, this really applies to any effort associated with the administration of any kind of information. Assuming that this is indeed the case, Computing for KM is of course found struggling to establish a unique, distinctive and strategic position.

It is therefore essential that those involved in Computing for KM locate and take up a comprehensible, distinct and unique strategic position to clearly differentiate the field from general or even special purpose Information Systems. In this search it may be instructive to lean on the research field of *Organisational Strategy*. Existing research in the fields of cognitive psychology and the social sciences provides a perfectly suitable and highly valuable set of design instructions on how to facilitate an enjoyable learning experience that successfully supports the transfer of knowledge. Research on Human-Computer Interaction, Visualisation, Knowledge Visualisation and Knowledge Maps is another area that provides amble hints and clues on how to achieve the aforementioned goal.

The reasoning behind Visualisation is very simple. Drawing a diagram or sketch makes it much easier to express and understand what a concept, idea, relationship, etc. is all about. Visualisation supports the conveying of meaning and the transfer of knowledge. Visualisation and KM therefore are a perfect match. In this context it is important to realise that, no matter how sophisticated the technology in the background

may be, the user sitting in front of a computer can only perceive the interface. Modern computing capacity has advanced to such an extent that, the KM technologist is practically invited to make use of Visualisation in the design of those interfaces. Visualisation of course is a wide field of inquiry. The most important subset for the KM technologist is Knowledge Visualisation. This area, which includes Knowledge Maps, has an exceedingly strong focus on transferring knowledge from the creator(s) to the users(s). In the creation of knowledge maps, knowledge and its relationship are captured and represented in a way that supports the cognitive processes of anybody viewing the final product. The KM technologist is called on to toil towards an understanding of the psychology behind this and to figure out how to best implement such features. Thus the disparate fields of cognitive psychology, the social sciences and the computer sciences are merged into a new whole that will help to establish computing for KM as a distinct and unique field of study and practice.

1.2 Research Problem

The existing research if the fields relevant to computing for KM may be described as a matter of extremes. KM related research very often is dealing with very specific and high level implementations of some KM principles in a particular organisation. It is next to impossible to generalise from the findings since it is insufficiently clear what the determining variables really are. A separation of cause and effect therefore is not really possible. Much of the literature on KM is very verbose, so much so that it is not too far fetched to describe the message as being drowned out by the words. Research in the fields of cognitive psychology has of course no KM focus whatsoever. It deals with individual, minute issues and provides results that need to be pulled together before the findings can be considered for application in KM. Studies on visualisation for instance examine human perception from different angles and always in isolation. This of course is precisely how it must be done, but the findings must be tested again in a KM context. The context or container of KM must be expected to impact on the user's perception of individual images.

This research endeavours to set a new mark that is located between the extremes. It terms of KM it takes a step back from the prevalent high-level and individually

specific case-study approach. It aims to supply *Grundlagenforschung* (a German term with no direct or specific English equivalent), that is research that seeks to find the right questions to be asked, thus providing the foundation for the kind of research which can be found in the field of the applied sciences. At the same time it seeks to include already existing *Grundlagenforschung* and research ranging from the fields of cognitive psychology to knowledge maps into its design.

1.3 Research Objectives

This dissertation sets out to show that there indeed can be a specific role for computing in KM. In order to do so, it first needs to be established that KM indeed is a truly independent field of research and practice. This goal can be accomplished by separating KM as the implementation from "*The Dynamic Theory of Organisational Knowledge Creation*" (Nonaka, 1994) as its theoretical foundation. This makes it possible to isolate the issue of effective knowledge transfer as the focus point of the endeavour just as it is stipulated by the aforementioned theory.

The experiment section of this dissertation presents a very simple knowledge base. It comprises set of files that contain information or knowledge about a specific subject area divided into four specific areas of expertise. That knowledge base is fronted by two different types of knowledge maps.

One is the very simple standard tabular listing of experts and their specific section of the knowledge base. The content of the knowledge base can be accessed directly from there. Many organisations use such features, commonly known as *Yellow Pages*, in the form of spreadsheets or simple web pages that are located somewhere on an intranet.

The second knowledge map interface is of a graphical nature with two layers. The upper layer identifies the four areas of expertise and provides the details of the associated experts. The lower layer features a very simple concept map for each of the areas of expertise. The content of the knowledge base can be accessed through that concept map.

The experiment seeks to find out about the following issues.

❑   Does a graphical interface compared to a standard tabular interface produce better results in terms of successful knowledge transfer? In other words, will the group that was presented with the graphical interface be able to recall more details than the group that was presented with the tabular interface?

❑   Will the users be able to easily identify the full functionality of the individual components presented on the screen? In other words, can it be determined is either interface supports the cognitive processes of the user better than the other?

❑   Are there any known or unknown variables that must be taken into account when embarking on such an endeavour?

❑   What kind of particularly technical issues will be encountered during the implementation of such an experiment? Do these issues produce hints as to what to watch out for when a real version of such a system is implemented?

1.4 Research Methodology

1.4.1 Qualitative Research

This dissertation offers an extensive literature review presenting and discussing the areas of KM, computing for KM, visualisation, knowledge visualisation and knowledge maps. This literature review focuses on academic publications rather than web resources. It strives to provide the reader with an understanding of the areas involved and the reasoning behind the rationale of the experiment.

1.4.2 Quantitative Research

Primary data is collected through a software tool developed to house the experiment itself. The data is designed to provide insights in the people and their behaviours,

preferences and needs in terms of knowledge acquisition. The data gathered comprises the following items.

❑ Statistical questions and participants' responses to the same for analysis.

❑ Duration of the whole experiment and its constituent parts.

❑ Participants' activities during the experiment.

▪ Mouse cursor movements by capturing nature and duration of 'hover-over' events in relation to specific screen objects.

▪ Number of knowledge file opened.

▪ Length of time a file is kept open.

❑ Recall test questions and participants' responses.

1.4.3 Experimentation

The development of software tool and to extent the experiment itself is conducted in two distinct stages. A feature-heavy prototype is developed and put to the test by individuals volunteering to evaluate the tool and the content of the experiment. The results of this trial run are evaluated in order to determine adaptations and changes that need to be made. The lessons learned flow into the development of the second iteration of the tool, which then is presented to a wider public for the implementation of the actual experiment.

1.4.4 Statistical Analysis

The type of experiment chosen is generally found in the fields of psychology in general and experimental cognitive psychology in particular. This requires that the statistical analysis be carried out in alignment with these fields. The datasets for evaluation therefore must be tested for normality even before any other analysis is carried out. The best options for such a test are either the Kolmogorov-Smirnov (larger sample) or the Shapiro-Wilk (small sample) tests. If the data is found to be normative a standard t-Test for statistical significance can be carried out. Otherwise the non-parametric Mann-Whitney U test is considered a suitable option.

1.5 Resources

Significant use of the DIT electronic library was made throughout. The dissertation was typed in Microsoft® *Word 2000* and *StarOffice 8 Writer*. All graphics originally created for this dissertation or replicated and derived from existing research sources were produced using a combination of Microsoft® *Paint*, Microsoft® *Visio 2002*, *PaintShop Pro 4.10*, *StarOffice 8 Draw* and *CorelDraw*® *7*. The software tool developed and deployed to house the experiment was written in Microsoft® *Visual Basic 6* (SP6). The statistical analysis of the experiment data was conducted using SPSS 16. The final PDF version of this dissertation was created using CutePDF[TM] Writer, a free tool provided by Acro Software Inc. and available for download at http://www.cutepdf.com/Products/CutePDF/writer.asp.

1.6 Scope and Limitations

This dissertation deals with a very narrow section of the wider field of KM. It is only concerned with the type of KM that seeks to implement the "*Dynamic Theory of Organisational Knowledge Creation*" (Nonaka, 1994). The research areas of knowledge transfer, knowledge visualisation and knowledge maps are considered in depth. Research topics like expert systems, data mining, data and information

visualisation, etc. are touched on but are neither the subject nor the focus of this dissertation. Technical aids in Computer Mediated Conversations while of great interest and importance particularly on the issue of persistence (Mengis and Eppler, 2005) are beyond the scope of this dissertation.

1.7 Organisation of the Dissertation

The dissertation features seven chapters, each dealing with a specific section of the project. Chapters Two through to Seven are organised as illustrated in *Figure 1.1* below. It may be noted that "*The Dynamic Theory of Organisational Knowledge Creation*" (Nonaka, 1994) henceforth is abbreviated OKC.

2		3		4
WHAT & WHERE		**WHY**		**WHY**
Knowledge Management		Visualisation		Experiment Design
OKC		Knowledge Visualisation		Experiment Distribution
Knowledge Transfer		Knowledge Maps		
Computing for KM				

5		6		7
HOW		**WHAT**		**CONCLUSIONS**
Prototype		Experimentation		Computing for KM
Trial Run		Issues Encountered		Visualisation
Final Implementation		Results		Knowledge Maps
Distribution		Discussion		Experimentation

Figure 1. 1: Dissertation Organisation

1.7.1 Chapter Two

Chapter Two opens by addressing the confusion that surrounds KM and computing for KM. Reasons will be proposed as to why this may be so. It will be shown that, in order to eliminate this confusion it is necessary to separate KM from its theoretical basis, which is OKC. A search for the existence of a dedicated role for computing for KM will conclude that there is no such role at this point in time. However, the argument will be made that such a role could come into being provided KM technologists embark on a search for a suitable area. An examination of the need for the effective transfer of knowledge will highlight that this issue that is at the core of OKC also is the most promising area for computing for KM to take up a distinct and unique strategic position in the world of computing. It will be argued that KM technologists must not rely on business related KM literature to achieve this goal. Instead it is necessary to draw on the fields of cognitive psychology, the social sciences and the computer sciences.

1.7.2 Chapter Three

Chapter Three addresses some specific challenges faced by the KM technologist in an environment where face-to-face contact as a means of communications is not always possible. It is shown why visualisation is a promising field as a source of further work and research. Knowledge visualisation and knowledge maps will be identified as the specific areas of inquiry the KM technologist must look into. It will be shown why and how knowledge maps are an appropriate choice to facilitate the transfer of knowledge as stipulated by OKC.

1.7.3 Chapter Four

Chapter Four explains the design of the experiment and introduces the different design decisions that determined the nature, look and feel of the same. The requirements for the experiment as well as the tool will be listed and accounted for. It will be shown

how the findings of Chapters Two and Three have been implemented. The separation between the experiment itself and the software tool housing it will be described and justified. Deliberations on the approach to the distribution of the experiment complete this chapter.

1.7.4 Chapter Five

Chapter Five discusses the actual implementations of the experiment and the software tool housing it. It will be shown that VB6 is the best option, since it allows for swift software development and features all the capabilities needed to satisfy the requirements. An outline on specific technical details will be provided in order to clarify the benefits from the approach taken. The prototype and the results of the trial run explain the changes and adaptations made to the final experiment. The distribution approach will be shown to be the compressing of all project files into a single ZIP file to be placed on a website for download. Participation is solicited through email.

1.7.5 Chapter Six

Chapter Six presents the issues that were encountered during the execution of the experiment. It will be shown that the experience was not a smooth one. Participation was far lower than expected and much time had to be expended supporting participants who had technical difficulties with the handling of the ZIP file. This issue lead to the known loss of a number of participants in terms of this experiment. Several Mac users also made contact pointing out the fact that they were excluded from participation since the tool was a strict Windows implementation. The results of the experiment are presented and discussed. It will be found that in terms of the quantitative data gathered by the experiment H_0 is to be accepted. The hypothesis that a graphical knowledge map interface caters for more successful knowledge transfer than a tabular knowledge interface could not be supported. This, however, is not surprising if the small sample size is taken into account. The results nevertheless provide valuable and interesting insights.

1.7.6 Chapter Seven

Chapter Seven reflects on the overall project and the outcomes. It will be shown that the experiment as such was not a failure. It provided several insights that warrant further investigation. It is suggested that the experiment be developed further and repeated. The recommendation is made that it be carried out under controlled conditions and that a much larger sample is required. Given these conditions the experiment has the potential to yield much more useful information.

2   OKC, KM AND THE IMPLICATIONS

2.1 Introduction

The concept of KM has received much attention over the last few decades. The student of the field is confronted with a complex host of exuberant success stories, case studies and popular as well as academic publications. The whole model of KM undeniably appears to be highly confused, disjointed and unstructured. In this chapter reasons will be proposed to explain why this is so. It will be shown how much of the aforementioned disorientation can be resolved by separating the theoretical foundation (OKC) from its practical implementation (KM). The point will be made that currently there is no dedicated role for computing in KM. However, it will be explained that there can be such a role. The issue of knowledge transfer, which may be considered to be the driving force behind OKC and by extension KM, will be examined from that viewpoint.

2.2 Confusion about and Criticism of Knowledge Management

KM is not an altogether understood, appreciated and accepted concept. It may be seen as telling that, despite the large number of publications on the subject, Pereira *et al*. (2007) consider KM to still be in its embryonic stage. There indeed is considerable confusion about function and nature of KM and its technological implementations (King *et al*., 2002). The term KM has been used to describe anything from database management solutions to organisational learning (Ruggles, 1998).

Wilson (2002) found that the terms 'information' and 'knowledge' are used interchangeably in KM specific popular, commercial and academic publications. He stresses that such confusion may be acceptable in consultancy terminology or business practice but cannot be tolerated in academia. Wilson concludes that the whole issue of KM is nonsense and nothing other than an umbrella term that covers a whole range of

activities that have nothing to do with the management of knowledge but are simple information management. Jubilant rumination about what KM can and should achieve but fail to generalise or conceptualise the "*how*" and particularly the *"why"* do little to manifest the concept as a truly feasible solution to well known and understood problems. Storey and Barnett (2000) observe that mainstream writers on KM are *overwhelmingly optimistic*. This has not changed since the observation was made. Knowledge in the context of KM, Linden *et al.* (2007) find, has turned into excellent currency that can be attached to next to any system or application so to benefit in terms of public relations. Prusak (2001) recognises that KM as a concept is widely misunderstood and as a result might go down in history as a temporary hype.

2.3 Criticism and Confusion Addressed

The challenge of concretising KM is best approached by illuminating its philosophical foundations. Modern KM is built mostly on the work of Ikujiro Nonaka. As such it is rooted in Asian (Japanese) philosophy and thus is in stark contrast to Western reasoning (Andriessen and Van den Boom, 2007). Nonaka (1994) for instance asserts that information processing and problem solving, approaches the Western mind is most comfortable with, on their own are insufficient to truly explain for instance innovation. Such philosophy can be very difficult for the western mind to grasp (Andriessen and Van den Boom, 2007; Nonaka, 1998 p. 23).

- ❑ KM necessitates an inclusive organisational culture (Nonaka, 1994).
- ❑ KM calls for a holistic approach; an organisation is no machine but a living organism (ibid, p.25).
- ❑ KM requires shared experience within the organisation (Nonaka, 1994).
- ❑ KM is about effectiveness and not efficiency (ibid).
- ❑ The success of KM initiatives does not lend itself to be measured by traditional economic means like improved return on investment, lower costs, increased efficiency, etc. (Nonaka, 1998, p. 42).
- ❑ The driver of KM is the need for knowledge transfer or the activity of making the knowledge of individuals available to others (ibid, p. 26).

The issue of the very different philosophies is best demonstrated by comparing some prevalent views on knowledge.

Origin	Western Intellectual Capital Literature	Asian Philosophy
Dominant Metaphors	Knowledge as a thing that can be controlled and manipulated	Knowledge as spirit and wisdom
	Knowledge as information that can be codified, stored, accessed and used	Knowledge as unfolding truth
	Knowledge as resource that can be created, stored, shared, located, moved, and that is part of the input-throughput-output system of the organisation	Unity of universe and human self
	Knowledge as capital that can be valued, capitalised and measured; that is part of the financial flow and requires a return on investment	Unity of knowledge and action
	Knowledge as thoughts or feelings that are tacit but can be made explicit; that communicated and shared	Knowledge as illumination or enlightenment of an underlying, deeper reality
		Knowledge as essence-less and nothingness (Japan)
		Knowledge creation as a continuous self-transcending process
Reproduced from Source: Andriessen and van den Boom (2007) Table I. Metaphors for knowledge in East and West, p. 648		

Table 2. 1: Western and Asian Views on Knowledge

KM in practice manifests as a mixture of Western and Asian philosophical elements. The implementation is strongly rooted in metaphor. An inspection of the above table makes it obvious that the area under discussion carries a significant potential for misinterpretation (Hogg and Vaughan, 2002, p. 106) and thus confusion. It must also be considered that every organisation is a unique structure. Much of the literature on KM concentrates on the implementation of KM initiatives in specific industries or organisations. This may also explain much of the confusion since every initiative is context driven and specific to its organisation. OKC generally is not discussed separately from KM; the former instead is integrated into the latter. This dissertation proposes that not discussing OKC separately is a mistake. OKC in principle can be seen to relate to KM as a class in object-orientated programming relates to its

instances. Instances of the very same class can be deployed for many different purposes. It would not make sense explaining the class by one of its instances that serves a specialised purpose.

❑ OKC is a complex theory. Its integration into KM can lead to an oversimplification that covers its concepts into a mantle of deceptive simplicity. This on top of the reasons stated above may also lead to misinterpretation.

❑ OKC as laid out in "*A Dynamic Theory of Organizational Knowledge Creation (Nonaka, 1994)*", while certainly containing philosophical roots and elements, is a scientific theory.

❑ Yet its instantiation in KM as mainly derived from "*The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation (Nonaka and Takeuchi, 1995)*" could be viewed more fruitfully as philosophical rather than an exact science.

❑ If the onlooker accepts the conflicting nature of knowledge being both a flow and a thing the term KM no longer is an oxymoron (Snowden, 2002).

❑ However, KM perhaps might be better termed "*knowledge focused management*" (Huseby and Chou, 2003) or "*a knowledge-based view*" (Grant, 2008) of the organisation.

Regardless the term used for an instance of OKC, it deals with knowledge, a concept that has and is being debated for millennia (Nonaka, 1994; Ruggles, 1997, p 1; Alavi and Leidner, 1999; Gordon, 2000; Prusak, 2001; Burkhard, 2004; Fenstermacher, 2005).

2.4 Knowledge and its Relationship with Data and Information

KM cannot reasonably be discussed without addressing the complexity of the relationship between data, information and knowledge, where knowledge is the most complex of the items. This discussion, for the purpose of this dissertation, is kept as pragmatic as possible, given the philosophical nature of the issue.

2.4.1 Knowledge

Knowledge is a concept, Andriessen and Van den Boom (2007) explicate, that does not have a clearly marked out and delineated structure. It gets its structure through metaphor (ibid) and cannot be divorced from its use (Fahey and Prusak, 1998).

Knowledge, in the view of Nonaka (1994), is "*a multifaceted concept with multilayered meanings.*" He views information as a flow of messages, while knowledge is created by that very flow. The latter is related to human action (ibid). In other words, knowledge leads to the "*capacity to act*" (Hussi, 2004).

Knowledge, in short, can be defined as information processed by an individual thus enabling that individual to perform actions s/he could not have performed before.

2.4.2 Data, Information and Knowledge

Knowledge is related to both data and information, moreover the relationship is a matter of degree (Davenport and Prusak, 2000, p. 1). A datum is a discrete, objective fact about an event (ibid, p. 2). Information on the other hand can be defined as *"data that makes a difference"* (ibid p. 3) while *"knowledge derives from minds at work"* (ibid, p. 5) who have internalised, interpreted and used that information.

Bhatt (2001) views the relationship between data, information and knowledge as recursive and points out the difficulty to truly and definitively differentiate between the

terms data, information and knowledge. The boundaries are fluent. While technical delineations can be drawn quite easily, the true meaning depends on the context, the degree of organisation and interpretation (ibid). A single fact that would be classed clearly as data can be information to another individual or even knowledge to a yet another person (ibid). This corresponds to the view that, information becomes knowledge in an individual's mind, is then externalised where it again becomes information for another individual to pick it up and making it knowledge again (Alavi and Leidner, 1999). Yet nobody can pinpoint precisely at what point information becomes knowledge (ibid).

Alavi and Leidner (1999) point out the potential fallacy of presuming a hierarchy of data, information and knowledge. Hierarchical graphical representations like the knowledge pyramid (*Figure 2.1 left-hand side*), while not incorrect, might introduce undesirable ambiguity. A perhaps preferable option is depicted below on the right.

Reproduced from Source: Frey (2001) Figure 1. Data, information and knowledge, p. 40

Source: Bhatt (2001) Figure 1. The recursive relations between data information and knowledge, p. 69
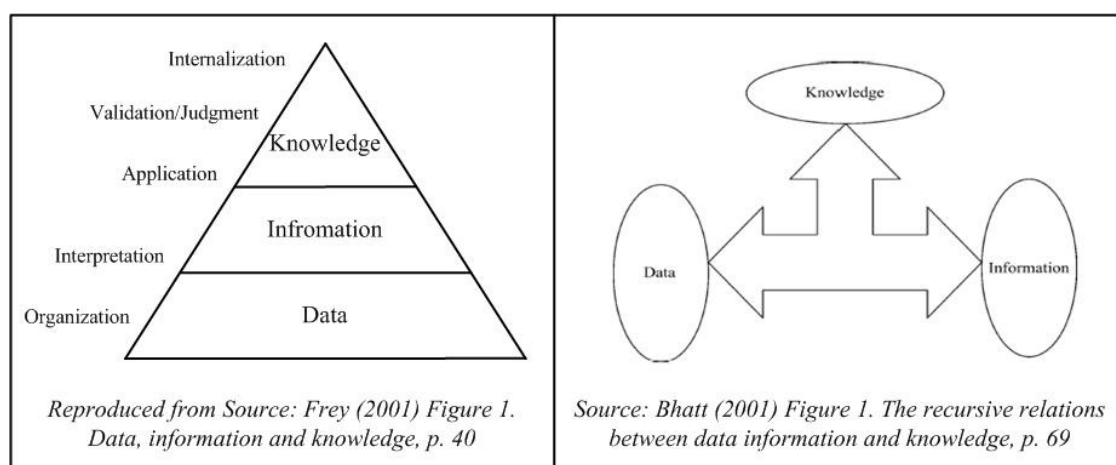
Figure 2. 1: Data, Information and Knowledge

2.4.3 Explicit versus Tacit Knowledge

The deliberations about the differences between tacit and explicit knowledge go back to Aristotle, who defined what we call explicit knowledge as the *know-what* and tacit knowledge as the *know-how* (Prusak, 2001; Fenstermacher, 2005). Explicit knowledge or the *know-what* is the kind of knowledge that can easily be put into words of any formalised language for documentation (Nonaka, 1994; Nonaka, 1998 p. 27; Eppler *et*

al., 1999; Davenport and Prusak, 2000, p. 70). Tacit knowledge on the other hand is internalised and accumulated by individuals over long periods of time and thus is very complex and personal. It is exceedingly hard to make it explicit for any kind of documentation (Nonaka, 1994; Davenport and Prusak, 2000, p. 70; Goh, 2002; Markus *et al.*, 2002; Terra and Angeloni, 2003; Alhashmi *et al*., 2006).

The relationship between tacit and explicit knowledge can be likened to program source code and comments inserted into the source code. Any programming language can be defined as a type of formal notation (Grogono, 1989) and can be learned even from books alone by anybody who is prepared to put in the effort. The source code therefore is a good example for explicit knowledge. Commenting on the other hand show all the hallmarks of tacit knowledge.

Comments are an annotation, used by programmers "*to insert documentation directly into source code*" (Storey *et al*., 2008). They are designed to help the reader understand the intended meaning of the source code (ibid). Good comments state what cannot easily be found out from reading the code (ibid). In other words, they say what cannot be expressed with code (Stroustrup, 2009 p. 46).

However, neither books nor tutorials can truly teach the writing of good and useful comments (Grogono, 1989). The quality of the comments within the code, in the view of Burkaloff (1984), depends primarily on the style and also intent of the programmer leaving the comments. In other words, experience and willingness are the key to good comments.

To comprehend the application of the above principles in KM, it seems prudent to draw from the source directly.

2.5 The Core of OKC

The dynamic theory of OKC as devised and proposed by Nonaka (1994) shows how knowledge held by societies, organisations and individuals can be enriched and enlarged simultaneously. It describes an organisation that has the capability and flexibility to constantly reinvent itself (Nonaka, 1998) through constant innovation such as is indispensable for any modern organisation (Pellissier, 2008). OKC can be applied to any kind of organisation, commercial, private, public or charitable (Nonaka, 1994). Even third level education could and should take advantage of OKC's principles (Ruth *et al.*, 1999). The theory proposes that both explicit and tacit knowledge can be transformed and generated in different situations. Nonaka (1994) traces the notion of convertible knowledge types back to the ACT (*Adaptive Control of Thought*, now superseded by ACT-R, *Adaptive Control of Thought - Rational*) theory developed by John R. Anderson for the field of cognitive psychology in the early 1980. The ACT/ACT-R theory defines two types of knowledge, *declarative* (explicit) and *procedural* (tacit), where the former can be converted into the latter through experience and practice (Anderson, 1993). It must be understood that the focus of OKC is on personal interactions between immediate teams, their surroundings and the whole organisation. While it has technical implications in general, OKC does not address the deployment of technology. The theory features four different modes of knowledge generation as inferred in the diagram below (*Figure 2.2*).

	Tacit Knowledge	Explicit Knowledge
		TO
Tacit Knowledge	SOCIALISATION	EXTERNALISATION
FROM		
Explicit Knowledge	INTERNALISATION	COMBINATION

Reproduced from Source: Nonaka (1994) Figure 1: Modes of the Knowledge Creation, p. 19
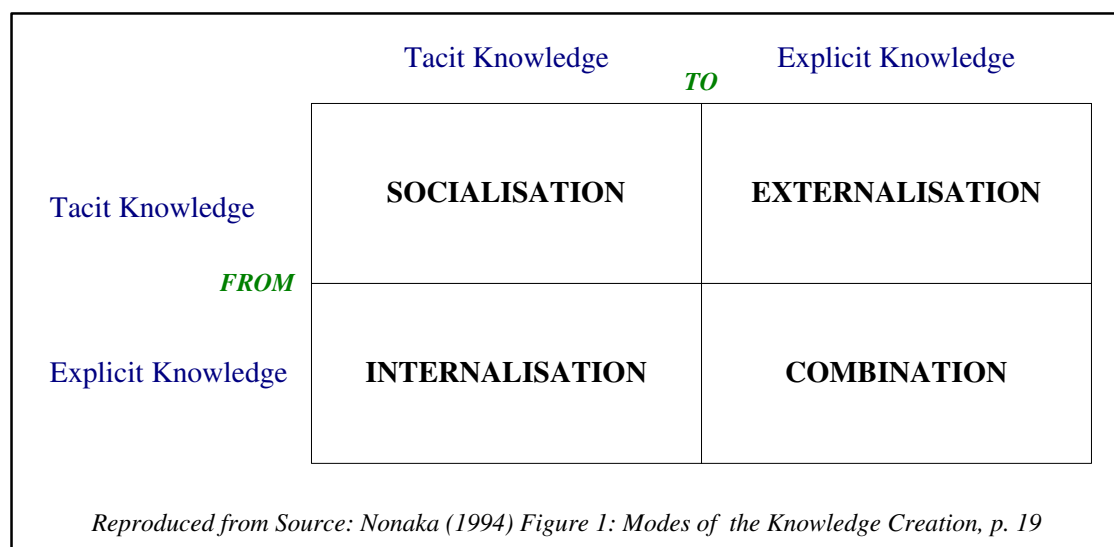
Figure 2. 2: Nonaka's Modes of Knowledge Generation

These four modes are in constant dynamic interaction with one another. The following four paragraphs contain a summary based on the explanations in Nonaka (1994), Nonaka and Takeuchi (1995, pp. 62 - 70) and Nonaka (1998, pp. 28 - 29).

The mode of *Socialisation* (tacit to tacit knowledge) is connected with elements of theories on organisational culture. Here social processes are used to combine the tacit knowledge of different individuals. On the job training or the apprenticeship exemplify some of the social processes in question.

The mode of *Externalisation* (tacit to explicit knowledge) describes processes making tacit knowledge explicit. This may happen through dialog, where an expert explains his/her tacit knowledge in a fashion that makes it comprehendible to non-experts. Here the use of metaphor and/or analogy finds fruitful application.

The mode of *Combination* (explicit to explicit knowledge) is connected with information processing on part of the individual combining different sets of explicit knowledge. The typical example would be an individual compiling a report using different sources of information.

The final mode of *Internalisation* (explicit to tacit knowledge) is much associated to organisational learning. It describes the situation where more and more staff begin to internalise the explicit knowledge made available throughout the organisation. The internalisation process depends on the application of the knowledge through practice and use. Knowledge creation is a continuous cycle of input and output (Huseby and Chou, 2003).

Furthermore, the four modes of knowledge creation do neither exist in isolation nor do they follow any particular order. Instead the processes described by the different modes happen concurrently, they are strongly intertwined and interdependent, contributing to and benefiting from each other (Alavi and Leidner, 2001) as shown below. The diagram below (*Figure 2.3*) illustrates a one-to-one relationship for the purpose of simplicity only. A many-to-many relationship as stipulated by OKC would be too complex to depict in any meaningful fashion.

INTERNALISATION

EXTERNALSATION

Tacit
Knowledge of
Individual
A

SOCIALISATION

Tacit
Knowledge of
Individual
B

EXTERNALSATION

INTERNALISATION

EXTERNALSATION

INTERNALISATION

Explicit
Knowledge of
Individual
A
Storage: document,
email, intranet, etc.

COMBINATION

Explicit
Knowledge of
Individual
B
Storage: document,
email, intranet, etc.

EXTERNALSATION

INTERNALISATION

After: Alavi and Leidner (2001) Figure 1. Knowledge Creation Modes

Figure 2. 3: Alavi and Leidner's Modes of Knowledge Generation

Nonaka (1994) views this "*dynamic entangling*" of the four modes as indispensable to mobilise tacit knowledge. Without this mobilisation of tacit knowledge an organisation is only a collection of individually knowledgeable individuals, the organisation itself is not creating any knowledge.

Here it is important to understand Nonaka's (1994) vital distinction between *individual* and *organisational* knowledge creation. Individual knowledge creation can take place within discrete modes even in some isolation.

Organisational knowledge creation on the other hand can only come to pass when *all* the *four modes are managed* by the organisation in such a fashion that they form a continuous cycle (ibid). This continuous cycle can be seen as a spiral as illustrated in *Figure 2.4* below.

Reproduced from Source:
Nonaka (1994) Figure 2, Spiral of Organizational Knowledge Creation, p. 20
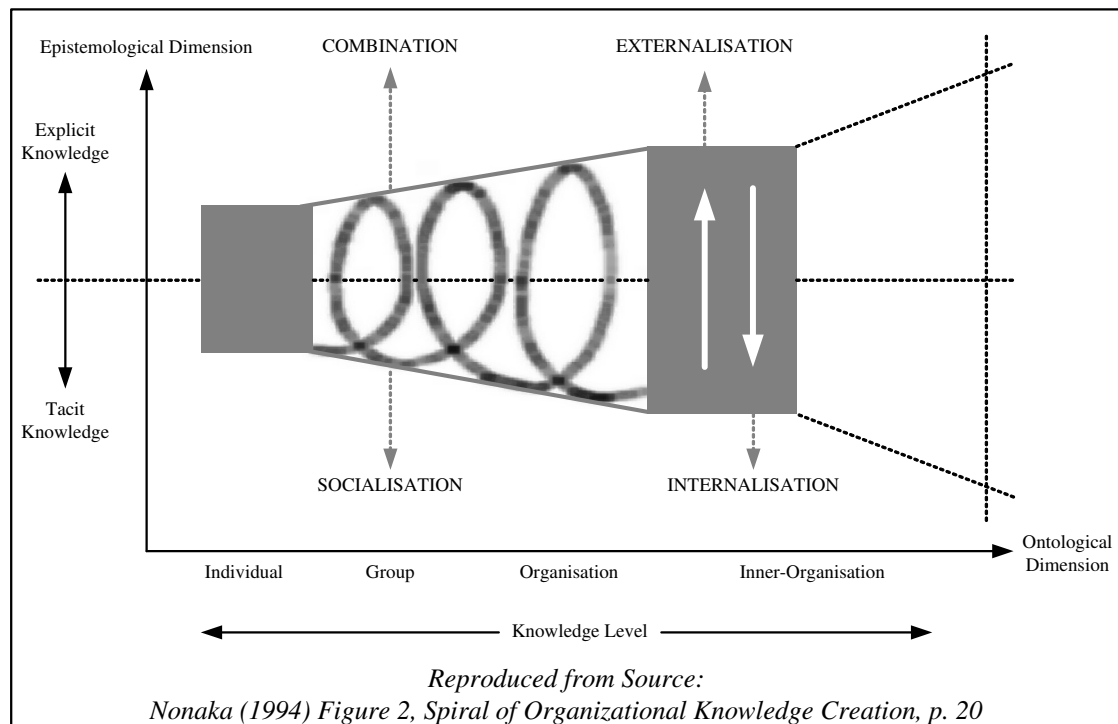
Figure 2. 4: Nonaka's Spiral of Organisational Knowledge Creation

Nonaka's (1994) dynamic theory of OKC therefore can be described as aiming to create an upwardly spiralling momentum where the continuous interactions between explicit and tacit knowledge in the epistemological dimension (here knowledge types) increase in scale and speed, drawing ever more individuals in and around the organisation into active participation.

The spiral in the ontological dimension (here knowledge levels), as depicted above, commence at the individual level and moved up to the collective and organisational levels, in ideal cases the spiral reaches even beyond the boundaries of the organisation itself (ibid).

The spiral can be said to be fully turning when all individuals at all levels are involved in the sharing and using of tacit and explicit knowledge available in the entire organisation. *Figure 2.5* below demonstrates this through maximum simplification. The link(s) to entities outside the immediate organisation have been omitted for clarity. It can be seen that OKC requires a many-to-many relationship of constant interactions between the tacit and explicit knowledge of individuals and groups.
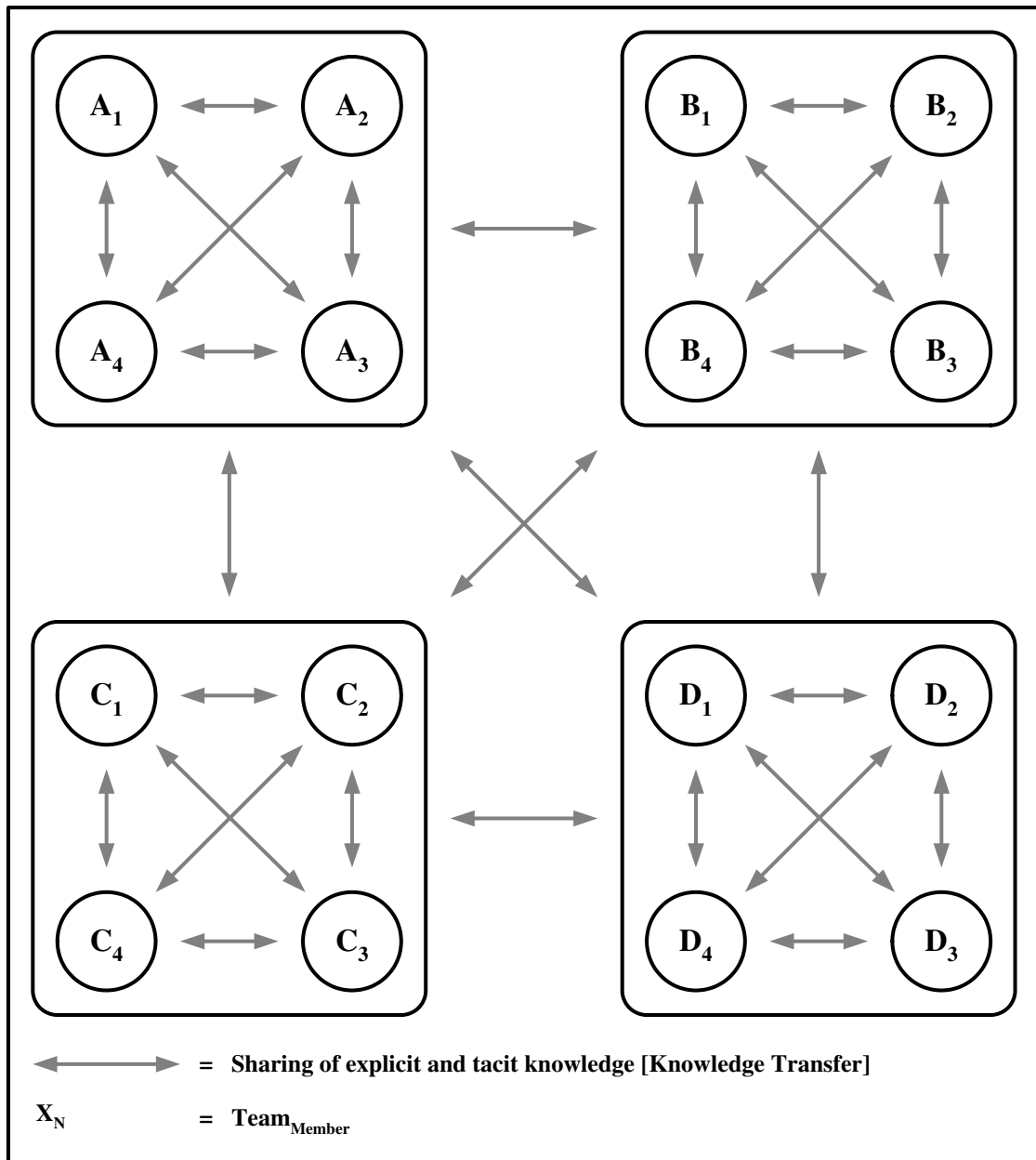
Figure 2. 5: OKC Compliant Interactions

2.5.1 Diagrams and the SECI Model

An example of a very popular type of depiction of Nonaka's (1994) "*spiral of organisational knowledge creation*" can be found in *Figure 2.6* below. This type of diagram must be viewed and interpreted with great care and consideration. Taken in isolation or explained with only a few words, it does not portray the true dynamics of OKC. While not incorrect as such, it can be seen as a simplification beyond the point of correctness and as such holds significant potential for misinterpretation. This type of

diagram cannot be found in Nonaka (1994), Nonaka and Takeuchi (1995) or Nonaka (1998).
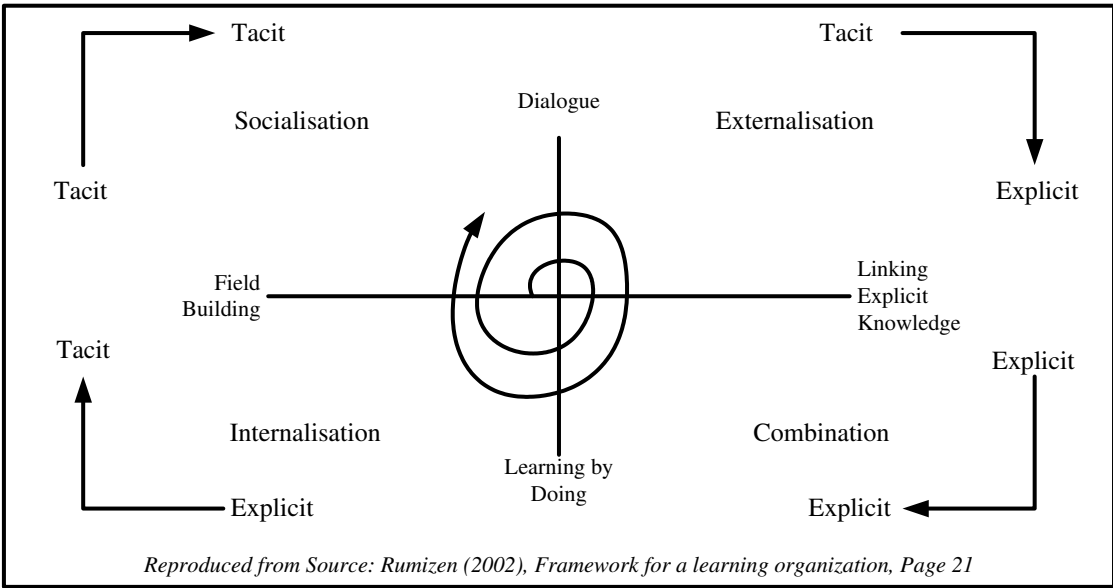
Figure 2. 6: Popular Type of Knowledge Spiral Diagram

Nonaka and Takeuchi (1995) do present a similar diagram as reproduced in *Figure 2.7*. As can be seen, however, it keeps a two-by-tow matrix structure and in the original is qualified by 36 pages of text, several tables and eight other diagrams.
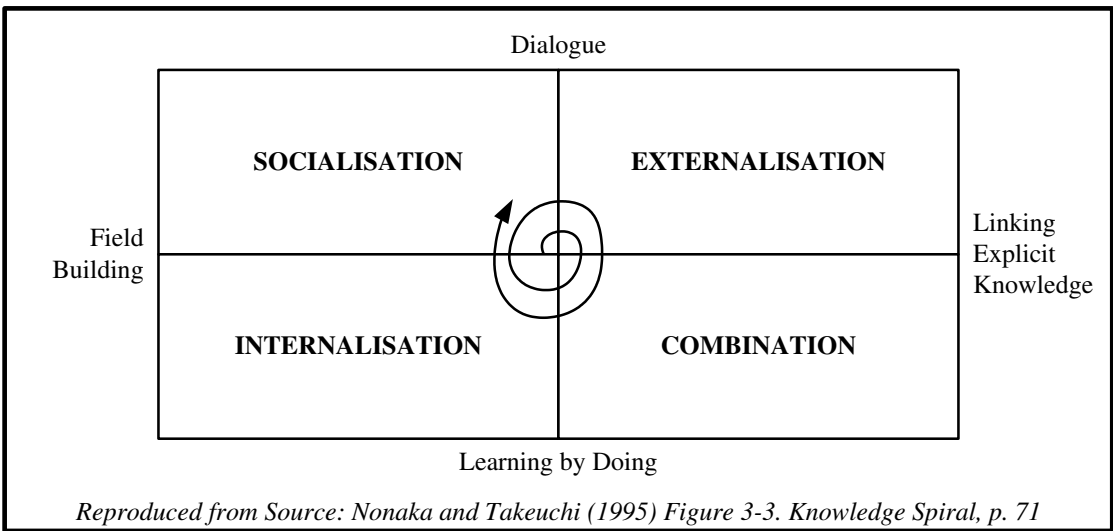
Figure 2. 7: Knowledge Spiral by Nonaka and Takeuchi

This dissertation proposes an additional diagram (*Figure 2.8*) in an attempt to capture the full dynamicity of the *Dynamic Theory of Organisational Knowledge Creation* (Nonaka, 1994). The diagram endeavours to emphasise that it is the empowered individual that powers the entire system.
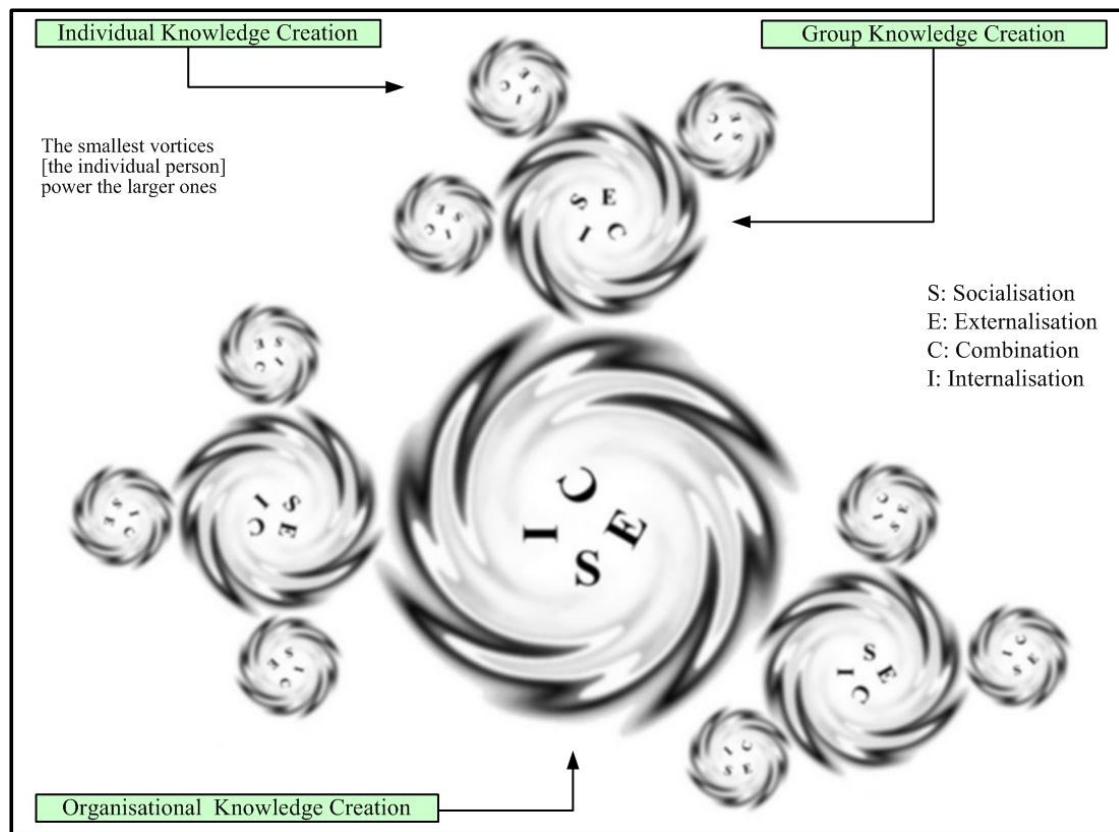
Figure 2. 8: The Dynamics of OKC

It seems self-evident that Nonaka's (1994) "*Spiral of Organisational Knowledge Creation*" (henceforth referred to as the *SPIRAL*) requires a suitable environment to initially start and then keep turning. A specific type of management philosophy is necessary to achieve the overall aim of OKC. KM attempts to be that management philosophy.

2.6 KM as an Instantiation of OKC

Greer (2008) describes KM as a collection of organisational processes that together generate new knowledge and lead to improvements on existing and/or future operations. Ruggles (1998), on the other hand, characterises KM as an approach designed to add or create value through the active leveraging of the existing know-how and expertise inside and in some cases even outside an organisation. Becerra-Fernandez *et al.* (2004) define KM with utmost simplicity as the endeavour of getting the utmost out of the existing knowledge in an organisation. Thus the philosophy of KM is all about creating an organisational structure that implements and keeps the *SPIRAL* going, producing ever more and deeper knowledge all across the organisation. In order to do so, a wide scope of practices is applied. Some practices are closer to OKC than others. The endeavour to introduce Western discipline (Maier and Remus, 2001) into KM by taking "*employee rank*" and strict "*process orientation*" into consideration is not people centric and thus not truly consistent with either OKC or KM.

2.6.1 The Knowledge Process

To implement the *SPIRAL* a high-level KM process-set must be formalised. Some strong similarities across the literature can be found here as exemplified in *Figure 2.9*. To be in compliance with OKC, this set of processes needs to cater for application at all, not only the organisational level.

Davenport and Prusak (2000)	Bhatt (2001)	Becerra-Fernandez *et al.* (2004)	Liyanage *et al.* (2008)
Generation	Creation	Discovery	Awareness
			Acquisition
Codification & Coordination	Validation & Formatting	Capture	Transformation
Transfer	Distribution	Sharing	
Use	Application	Application	Association
			Application

Figure 2. 9: The Knowledge Process

Before the *SPIRAL* can even start turning, there needs to be the awareness in the organisation that individuals hold a significant amount of valuable tacit knowledge. The precise locations of that knowledge must initially be determined (Liyanage, *et al*., 2008). Provided the sources as well as the receiver have the willingness and capacity to do so, the knowledge then needs to be acquired (ibid). Next, the knowledge must be verified and transformed in a fashion that makes it useful for the widest possible audience (ibid). After that the knowledge is ready for presentation.

However, the mere fact that knowledge has been presented by no means ensures that knowledge has been transferred (Davenport and Prusak, 2000, p. 101). This new knowledge must be absorbed and used or applied by the recipients (ibid; Alavi and Leidner, 2001, Bhatt, 2001; Liyanage, *et al*., 2008).

Once the knowledge has been internalised, the individuals, groups and the organisation are ready to raise awareness of the new knowledge created which is feed back and thus closes the circle. *Figures 2.10* to *2.12* generalise and depict this circle borrowing from the field of electronic engineering. Attention may be paid to the position of *Awareness*. It initially starts the cycle as an outside entity but then becomes part of the cycle itself. This is required to keep the cycle of the spiral going.
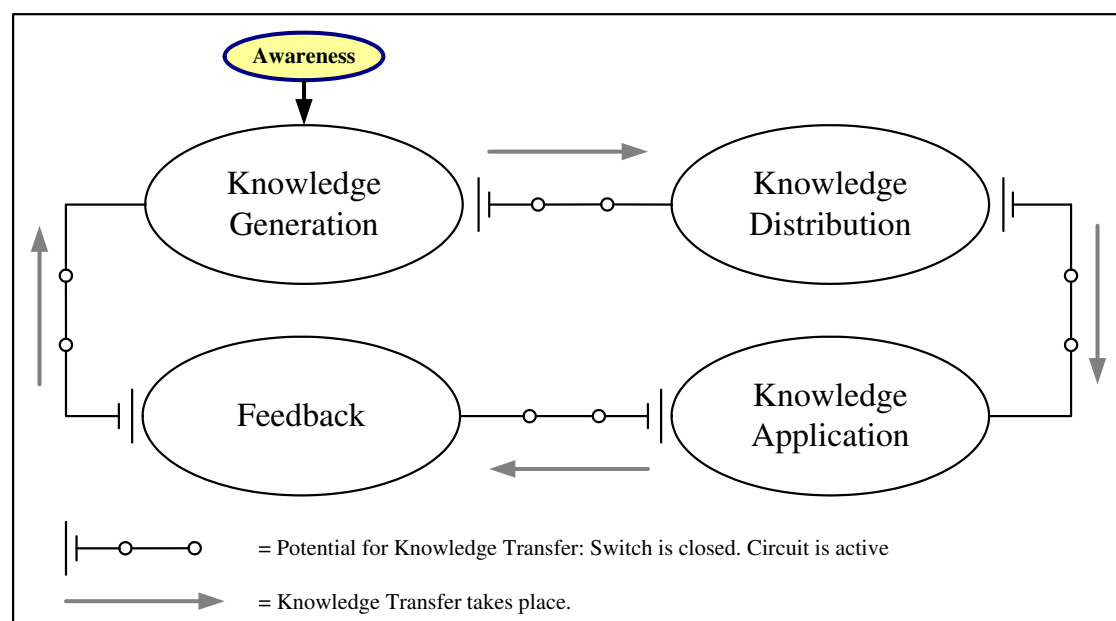
Figure 2. 10: The Knowledge Process - Initially
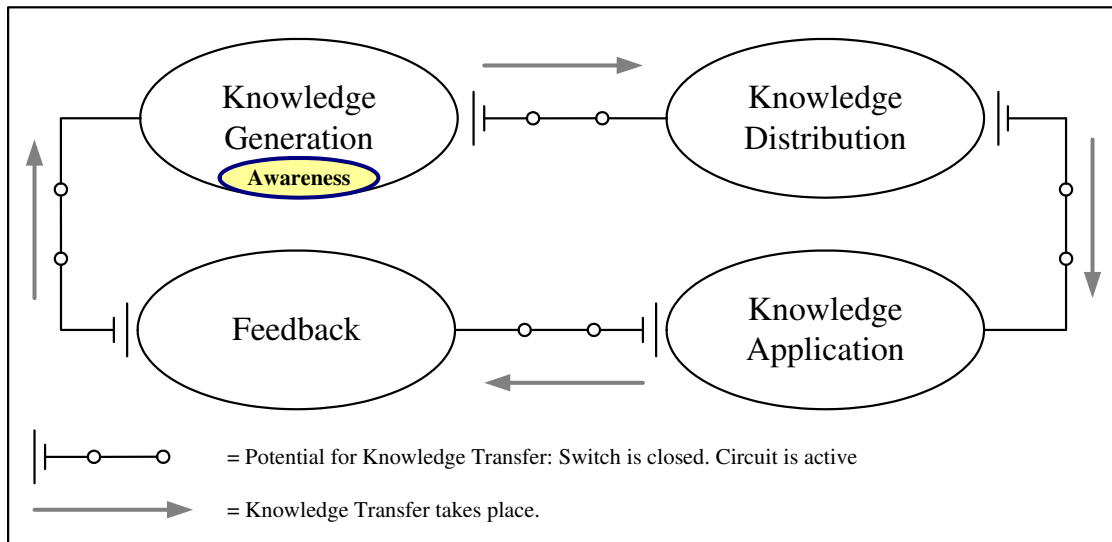
Figure 2. 11: The Knowledge Process - Continually

However, even if the initial instantiation was successful, continued success is not guaranteed. Failing to keep the *SPIRAL* turning will lead to a static repository of knowledge that very quickly loses relevance to "*the here and now*" as Nonaka (1994) puts it.
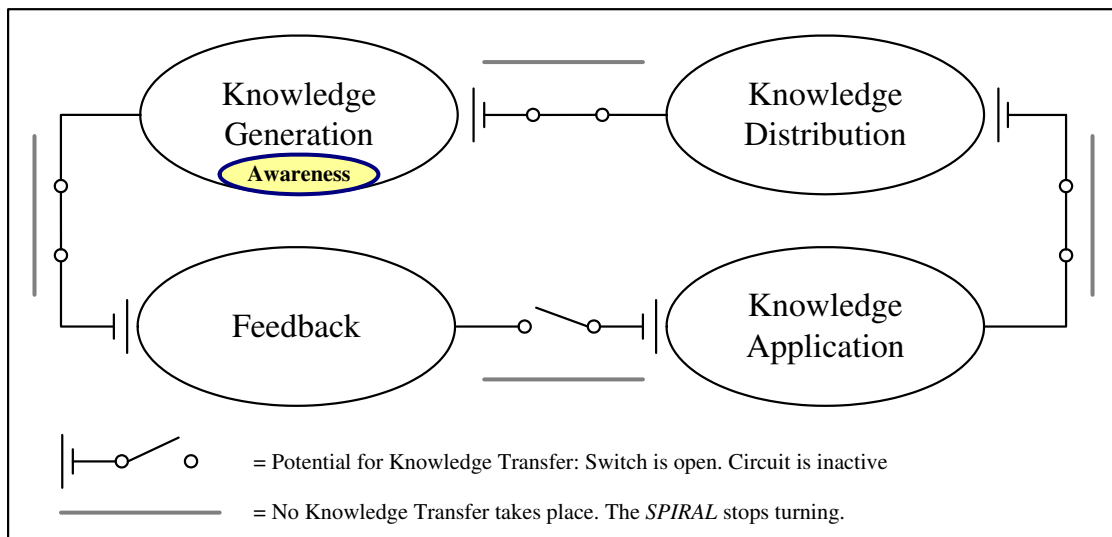
Figure 2. 12: The Knowledge Process – Failure

Even if the *SPIRAL* is instantiated completely, it can be brought to a halt by managerial actions or lack thereof. A break anywhere in the cycle is fit to stop the *SPIRAL* as illustrated in the diagram above. An organisation contemplating to implement OKC therefore must take several important managerial factors to take into account.

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2.6.2 Culture and Structure of the Organisation

OKC addresses the importance of the organisational culture. Organisational culture can be seen as the sum of the experiences and the unwritten laws on how things are being done and how individuals interact with one another (Furnham, 1997, p. 555 - 559). No KM initiative can function without the people involved being willing to share and in turn use shared knowledge (Terra and Angeloni, 2003, Liyanage *et al*. 2008). The culture within an organisation has a massive impact on the willingness of the individual to do so (Wiig, 1999; Storey and Barnett, 2000; Davenport and Prusak, 2000 p. 96; Prusak, 2001; Bhatt, 2001; Meier and Remus, 2001; Goh, 2002; Rao, 2002; Wagner and Bolloju, 2005; Guzman and Trivelato 2008; Su *et al*., 2007; Chan and Chao, 2008). An organisational top-down approach, where the higher echelons issue orders, does not foster the required commitment levels in the individual (Nonaka, 1998, p. 43). Organisations fostering an excessively competitive environment, as described in Furnham (1997, p. 575), may also find their staff unwilling to join in. The organisation instead needs to regard all its members as essential actors who cooperate horizontally as well as vertically (Nonaka, 1994). The *Adhocracy* as presented by Mintzberg and McHugh (1985) is a good example of an organisation that is ready for KM.

2.6.3 Holistic Approach

If a KM initiative truly implements OKC, the whole organisation in all of its aspects will be affected (Bhatt, 2001). Bixler (2002) maintains that KM must be embedded in all processes of the organisation. Just creating a KM department or some KM process is insufficient. Concentrating on one or two of the modes of knowledge creation is not implementing OKC. It requires all four modes for the *SPIRAL* to substantiate and turn. *Socialisation* on its own (e.g. a Community of Practice) creates tacit knowledge in a select group of individuals, however, that tacit knowledge is never externalised and made explicit (Nonaka, 1994). The situation is similar with the mode of *Combination* (e.g. a Knowledge Repository) on its own; here the stored explicit knowledge will interpreted only very superficially (ibid).

This is not to say that an organisation must implement the full requirements of OKC all at once. On the contrary, Storey and Barnett (2000) found that many KM initiatives, even very well funded ones, falter because the projects aim to implement too much too soon. They therefore suggest that it is better to start with one small element of OKC. However, the full benefits of the *SPIRAL* cannot be expected to materialise if no further elements are implemented.

2.6.4 Shared Experience

It is impossible for people to share their knowledge "*if they are not speaking the same language*" (Davenport and Prusak, 2000 p. 98). Shared context, experience and beliefs are indispensable for OKC to work (Nonaka, 1994; Nonaka, 1998; Fahey and Prusak, 1998; Marwick, 2001; Alavi and Leidner, 2001; Van Leijen and Baets, 2003; Bernard, 2006). If that is not the case, the psychological filters set up by individuals as described in *Transactional Analysis* (White, 2000, p. 70) will not allow for the level of communications that is required for the *SPIRAL* to turn.

2.6.5 Efficiency versus Effectiveness

OKC focuses on effectiveness. In contrast to that, Western management philosophy, as Nonaka (1994) points out, represents a very mechanistic view of the organisation. It focuses strongly on efficiency. However, the focus on efficient workflows does not consider the benefits of cognitive cooperation between team members. Knowledge, it can be said, is the result "*cognitive processing triggered by the inflow of new stimuli*" (Alavi and Leidner, 2001).

Zhuge (2003) exemplifies this by proposing concept of the "*cognitive flow*" versus "*work flow*" among team members. The "*cognitive flow*" not only supports the effectiveness of the team, it also grows and creates new knowledge. A summarised comparison of Zhuge's flows can be found in *Figure 2.13*.

Cognitive Flow	Work Flow
Reflects team member's cognitive cooperation	Reflects only cooperation in terms of work performed
Generated from task implementation of team members	Reflects the process only
Cannot be designed in advance	Can be designed in advance
Expands its content during execution through team work	Reflects the control of activities only

Figure 2. 13: Cognitive and Work Flows According to Zhuge

Zhuge (2003) points out that team members at the level of cognitive cooperation make abstractions, devise analogies spanning the whole problem, and use their skills and prior experience to solve new problems. In short, they "*learn from each other*" (ibid). The efficient but mechanistic workflow, leaving the individual to handle one isolated aspect of the whole, on the other hand, reduces creative thinking and the development of fresh knowledge (Nonaka, 1994). The cognitive flow does indeed help turning the *SPIRAL* while the workflow does not as demonstrated in *Figure 2.14.*
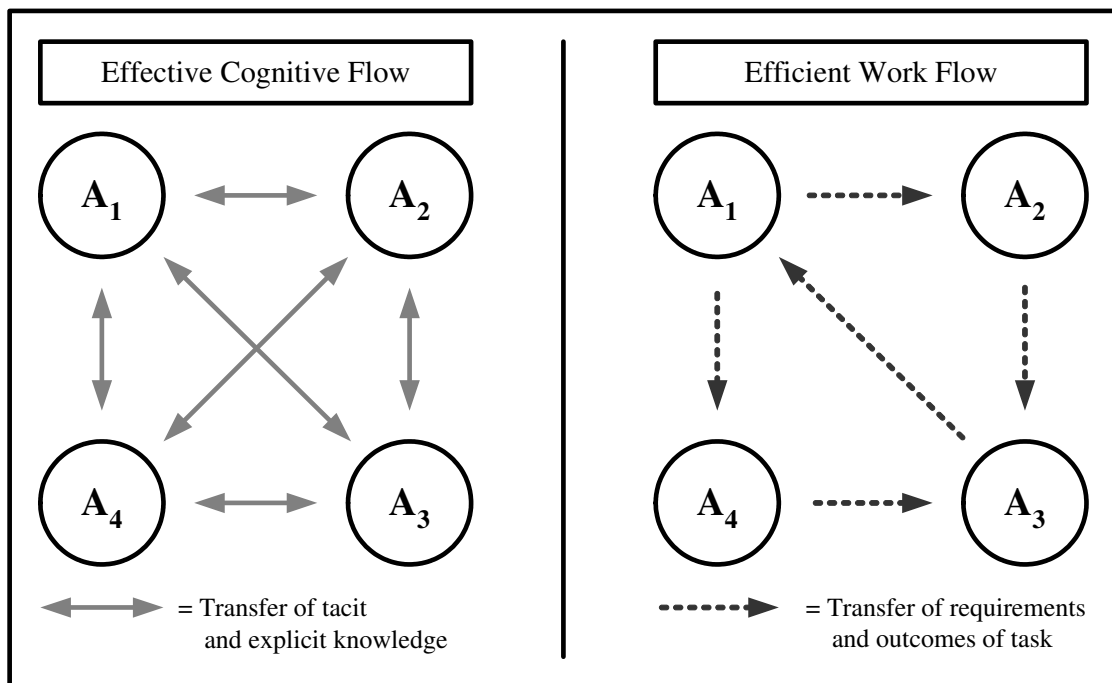
Figure 2. 14: Comparing Cognitive and Work Flows

2.6.6 Metrics

There is significant research into the application of metrics in KM (Oliveira and Goldoni, 2006). However, knowledge by its nature is very difficult to either monitor or control. Part of the organisational knowledge is internalised by the organisation, part by the individual (Bhatt, 2002). Metrics, Su *et al.* (2007) found, are highly inadequate to measure the success of any KM initiative. Robertson (2003) cautions that the impact of metrics on the individual must be taken into account. More than that, a fixation with traditional metrics, Fahy and Prusak (1998) assert, is in fact destructive to KM. The extra administrative and cognitive burden has the potential to slow and halt the *SPIRAL*.

2.7 Is KM worth the Effort?

The implementation of OKC through KM clearly is an undertaking that is not to be taken lightly. Significant exertion is required. The question arises whether or not it is worth the effort. It cannot be denied that the problems KM sets out to alleviate and solve are real and must be given attention. There indeed is something "*beyond the hype*" (Storey and Barnett, 2000). There are, Wexler (2001) notes, convincing and rather pressing reasons for knowledge to be managed more effectively.

❑ Our capabilities to capture and store data are outpacing our capacity of processing and exploiting it (Fayyad and Uthurusamy, 2002).

❑ Staff in the modern organisations is suffering from information and cognitive overload (Chen and Davies, 1999; Handzic, 2004; Marwick, 2001).

❑ Cognitive principles, while well researched in the context of Human-Computer Interaction, are simply not taken into account in the design of user interfaces for information systems (Levine, 2007).

❑ An organisation cannot use existing knowledge for the purpose of learning if that knowledge resides in individual's private domains, in mere knowledge repositories or in databases (Goh, 2002).

It can be concluded that the effort of implementing OCK through KM is indeed a valuable endeavour. The discussions in this sub-section have made it obvious that OCK and KM are organisational concerns. Neither is about technology. Now the question arises whether or not Computing can play a dedicated role in either OKC or KM.

2.8 The Role of Computing

Addressing the role of technology in the context of this dissertation means that technology is used to substitute or augment personal interactions as illustrated in *Figure 2.15*.
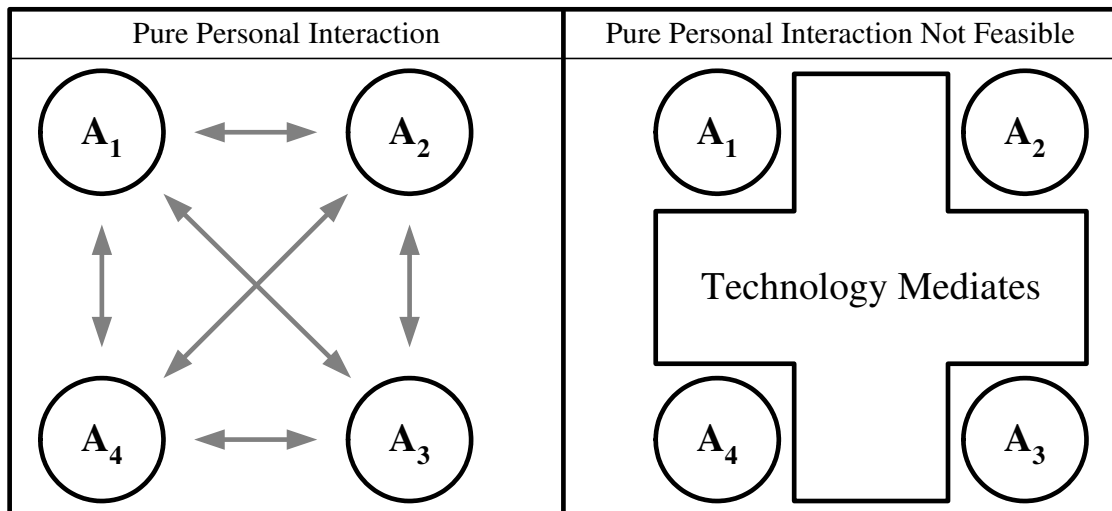
Figure 2. 15: Computing Facilitating Interaction

The mere implementation of technology obviously does not turn an organisation into a knowledge-creating organisation (Davenport and Prusak, 2000, p. 142). Technology in most literature does not feature prominently within KM as epitomized in *Figure 2.16* below.

Reproduced from Source: Bhatt (2001): Fig 3 – Knowledge Management Components and sub-elements
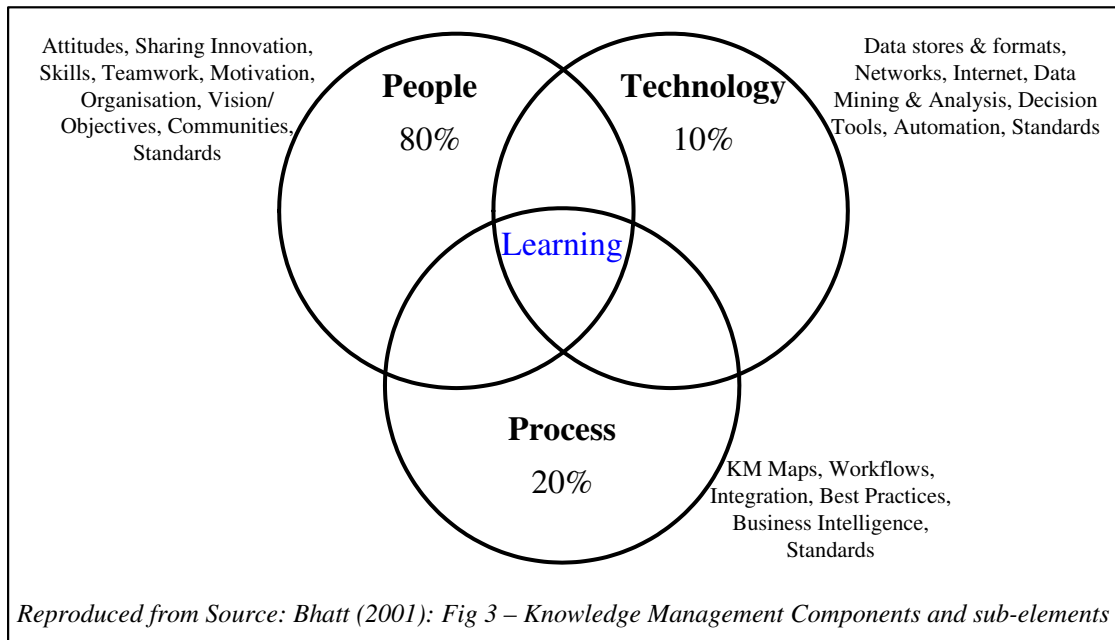
Figure 2. 16: KM Components according to Bhatt

Moffet *et al*. (2004) detect much confusion about the role of Computing for KM. They attribute much of this to the prevalent repacking of already existing software packages and applications using the label of KM. Prusak (2001) observes a tendency, particularly among software vendors, to reduce KM to the administration and moving around of documents and data, thus clouding the issue of knowledge (Gordon, 2000). There also is significant disappointment about the existing range of KM solutions (Rentinck, 2005); problems are solved by using old concepts. New systems and procedures are implemented that do not recognise the information or knowledge itself as the source for the solution (ibid). The situation is well reflected in the nature of technologies currently used in KM as exemplified in the *Figure 2.17* below. It can also be deduced that there is only very limited consensus.

Alavi and Leidner (2001)	King *et al.* (2002)	Moffet *et al.* (2004)	Bernard 2006
Knowledge Repositories	Knowledge Repositories	Content Management	Knowledge Repositories
Discussion Forums	Communities of Practice	Collaboration	Collaborative Tools
Electronic Bulletin Boards	Best Practice and Lessons Learned Systems		Expert Directories
Data Mining, Learning Tools	Expert Networks		
Databases		Business Intelligence	
Expert Systems, Workflow Systems			

Figure 2. 17: Technology Applications in KM

Most authors do not see computing as playing any specific role in KM, it is, however, deemed a valuable enabler (Davenport and Prusak, 2000, p. 143; Alavi and Leidner 2001; Bhatt, 2001; Rao, 2001; Bernard, 2006).

Technology does affect how the users behave (Davenport, 1997, p. 102; Marwick, 2001; Wexler, 2001; Graef, 2004; Hasan and Pfaff, 2006) and can positively affect learning (Alavi and Leidner, 2001).

However, Computing for KM currently is very much confined to using existing technologies (King *et al.*, 2002; Marwick, 2001, Bixler, 2001) for the purposes of

❑ Linking people together (Moffett et al., 2004).
❑ Creating favourable conditions for people to learn (Terra and Angeloni, 2003).
❑ Building bridges that takes the individual and the organisation into account (Su et al., 2007).

Nissen *et al.* (2000) assign a slightly more distinct role to Computing for KM. They approach the issue from a standpoint of system analysis and design, innovation and integration. Existing technologies should not just be used but need to be adapted specifically for the use in KM (ibid).

2.8.1 Examining Technologies

Marwick (2001) observed that there are no true KM solutions on the horizon. There are a number of technologies that have been described as KM solutions. Any technology, in order to be OKC compliant must

❑ Feature a many-to-many relationship.
❑ Support the transfer of explicit and tacit knowledge between humans.
❑ Sustain a cognitive flow.

2.8.1.1 Expert Systems

Expert Systems fall into the realm of automation. Some of the main motivations behind or benefits gained from the introduction of expert systems are increased efficiency and the reduction of the number of staff required to perform very complex tasks (Byrd *et al.*, 1996) as illustrated in *Figure 2.18*.
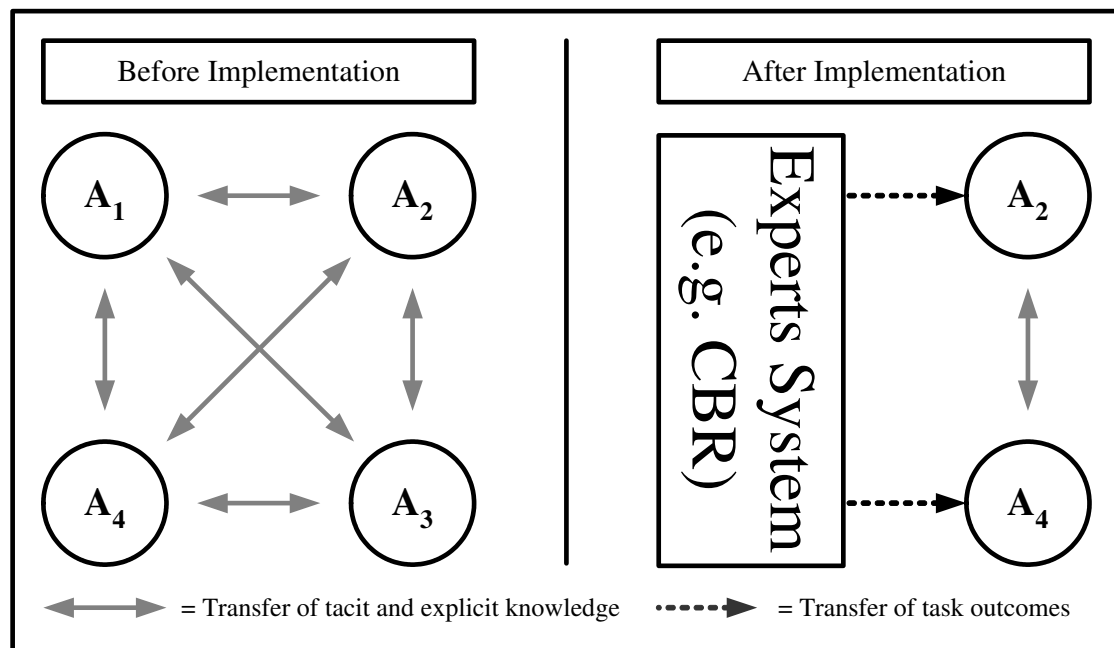
Figure 2. 18: Expert Systems

```
Relationship type:    none, human-to-machine
Cognitive Flow:       eliminated or reduced
Knowledge Transfer:   to some degree
```

Neither the drive for efficiency nor staff reduction is consistent with OKC. Expert systems in the context of this dissertation are therefore not considered KM solutions.

That is not to say the technologies concerned have no place in KM. On the contrary, artificial intelligence and expert system technology can be deployed. Cañas *et al.* (1999) suggest that it can be very beneficial to connect for instance a front-end concept map tool witch a back-end case based reasoning system.

2.8.1.2   Decision Support and Executive Information Systems

Decision Support Systems (DSS), Executive Information Systems (EIS) and similar software applications are often listed as part of KM. However, with such systems only the upper echelons of the organisation are empowered to create knowledge and information (Nonaka, 1994) thus forming a form of *Information Feudalism* (Davenport, 1997, p. 72). Yet Drucker's (1998, p. 5) knowledge working specialists are found at the operations level, not at corporate head quarters.
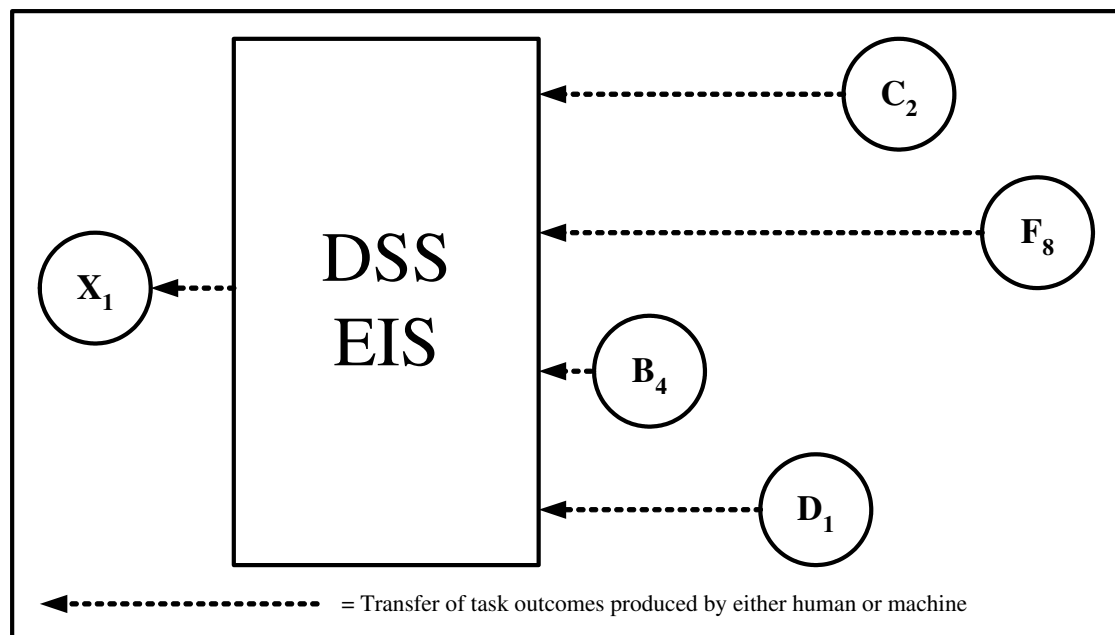
Figure 2. 19: DSS and EIS

```
Relationship type:     one-to-many
Cognitive Flow:        none
Knowledge Transfer:    no
```

Decision Support Systems (DSS), Executive Information Systems (EIS) in the context of this dissertation are therefore not considered KM solutions.

2.8.1.3   Data Mining

Data mining is concerned with the detection of interesting patterns hidden in large volumes of archived data (Andrienko and Andrienko, 1999, Fayyad and Uthurusamy, 2002). New information and knowledge are undoubtedly discovered. That new knowledge then can be externalised and fed into the SPIRAL. Yet the data miners do not gain this knowledge from interacting with humans by tapping into their tacit knowledge. Wang (2002) warns that an over-emphasis on the discovery of knowledge by such means can damage the KM effort by distracting from human knowledge development.
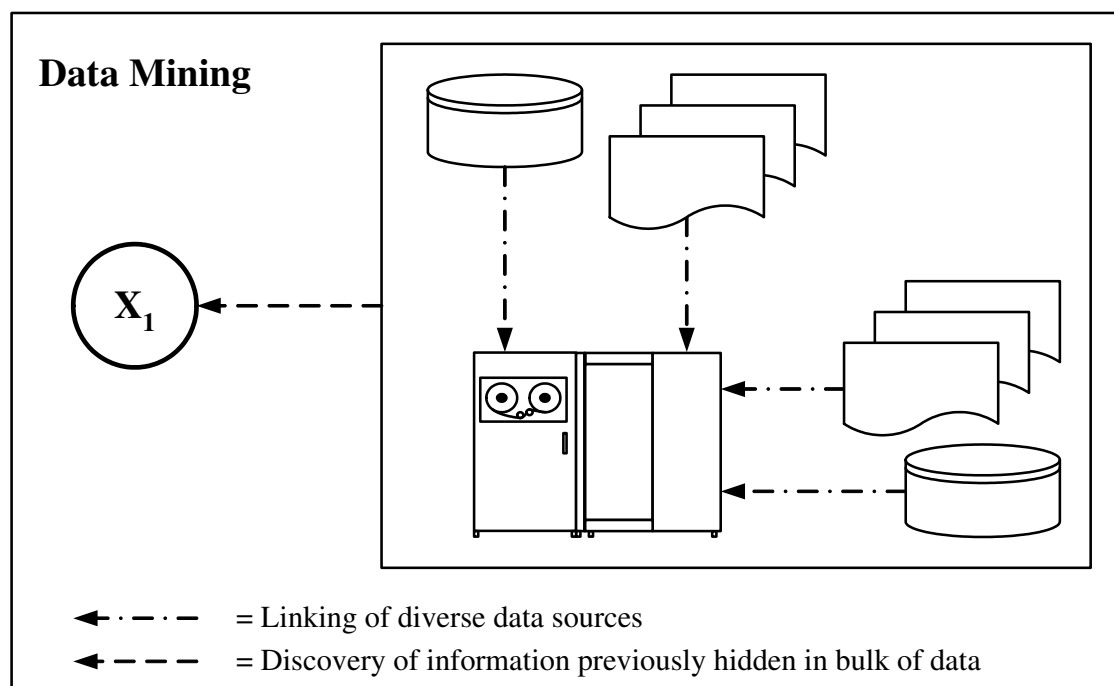
Figure 2. 20: Data Mining

```
Relationship type:     no human relationships
Cognitive Flow:        none
Knowledge Transfer:    no
```

Data mining in the context of this dissertation is therefore not considered a KM solution.

2.8.1.4   The Wiki

The Wiki is an emerging collaborative technology that may have the potential to change the outlook on Computing for KM significantly. It is an innovation that certainly warrants special consideration (Hester, 2008). Wagner (2004) maintains that a KMS must make it easy for the user to find, share and express knowledge. The Wiki certainly does that.
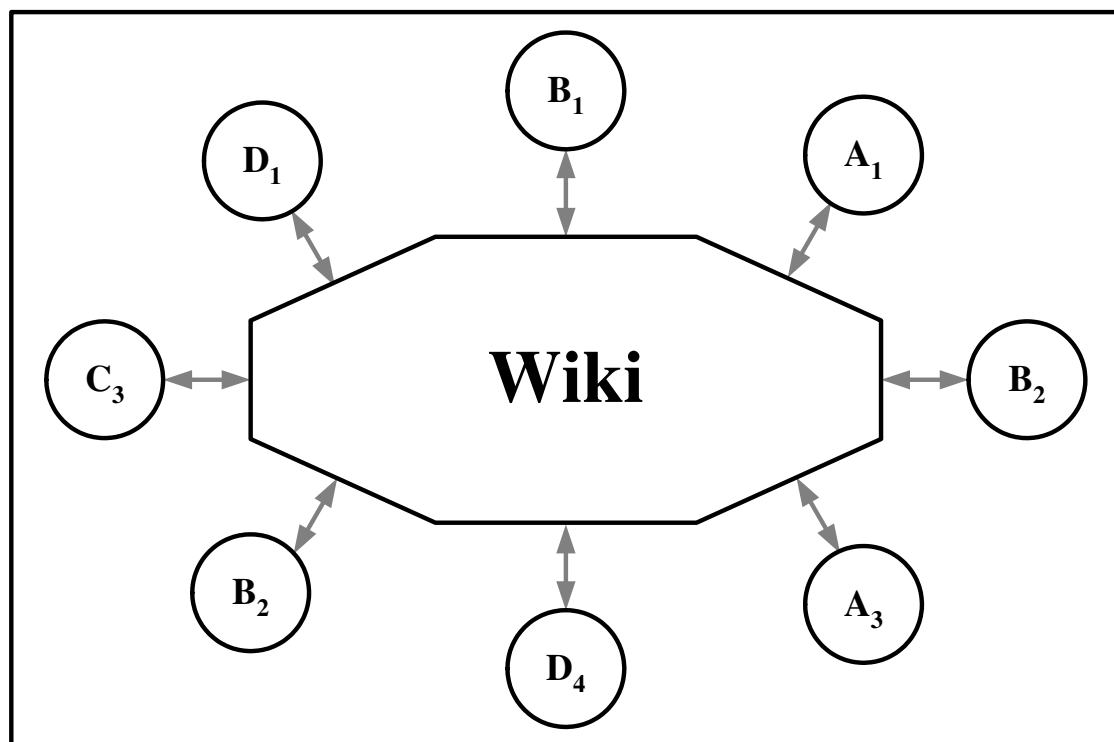
Figure 2. 21: The Wiki

```
Relationship type:    many-to-many
Cognitive Flow:       yes
Knowledge Transfer:   yes
```

However, the Wiki suffers from the problem of quality (Hasan and Pfaff, 2006). Everybody can contribute, but it has no feature to assure common ground and shared meaning.

The Wiki may well become a KM tool in the future, but much research will be required before a definite judgement can be drafted.

2.8.2 Computing for KM

It would appear that Marwick's (2001) assessment, with the potential exception of the Wiki, is still valid. Fenstermacher (2005) takes up a different position from most authors in the field of KM. He argues that it might be unwise to conclude on purely philosophical grounds that tacit knowledge will never be representable by technological implementations. A "*richer cognitive model*" and specific research is likely to detect a strong and specific role for Computing for KM (ibid). Such research needs to be conducted within the field of the computer sciences but must take the cognitive processes and capacity of the users into account.

This is not an isolated view. Alavi and Leidner (2001) discern that theories in terms of KM are principally geared towards explaining the organisational implications. They call for theories and research into the design and use of KM systems.

In this context, awareness of the importance of metaphors is imperative. KM technologists need to consider terminology carefully; metaphors do matter (Nardi and O'Day, 1999, p. 27). OKC is human-centric and so must any technical implementation that supports KM (Zachry *et al.*, 2001). The term *system*, in people's minds, can raise the mental picture of being caught in and being controlled by it (ibid). The term tool on the other hand conveys the image of handling something that can be learned and controlled (ibid, p. 28). From hereon in the term *system* will be abandoned in favour of the term *tool*.

In the search for a distinctive role and position of Computing for KM it can be instructive to lean on the research field of organisational strategy. Porter (1996) and Markides (1999) argue that strategy is about selecting a unique position by performing activities that are different from the competition. The concept of "*core competencies*" as put forward by Prahalad and Hamel (1990) shows how these different activities can lead to great flexibility and adaptability.

These can be valuable clues for KM technologists. The activities performed through and by a KM tool must be different from the activities performed through and by

Information Systems. The core competencies in particular must be different. Approaching the issue from this angle it can be seen that there is significant room for differentiation.

Kühn and Abecker (1997) describe the process of knowledge transfer as one of the most critical aspects in knowledge management. It is fundamental to any knowledge management initiative (Albino *et al.*, 2004). However, the true value of technologies in supporting the transfer of knowledge is yet to be fully understood (ibid). It therefore makes sense to investigate the transfer of knowledge as a potential core competency.

Only a cross-disciplinary approach can lead to such a research and development effort being successful (Card, Moran & Newell, 1983 p. 1; Prusak, 2001; Terra and Angeloni, 2003). *Figure 2.22* provides an overview of the position and role of Computing for KM as proposed by this dissertation.
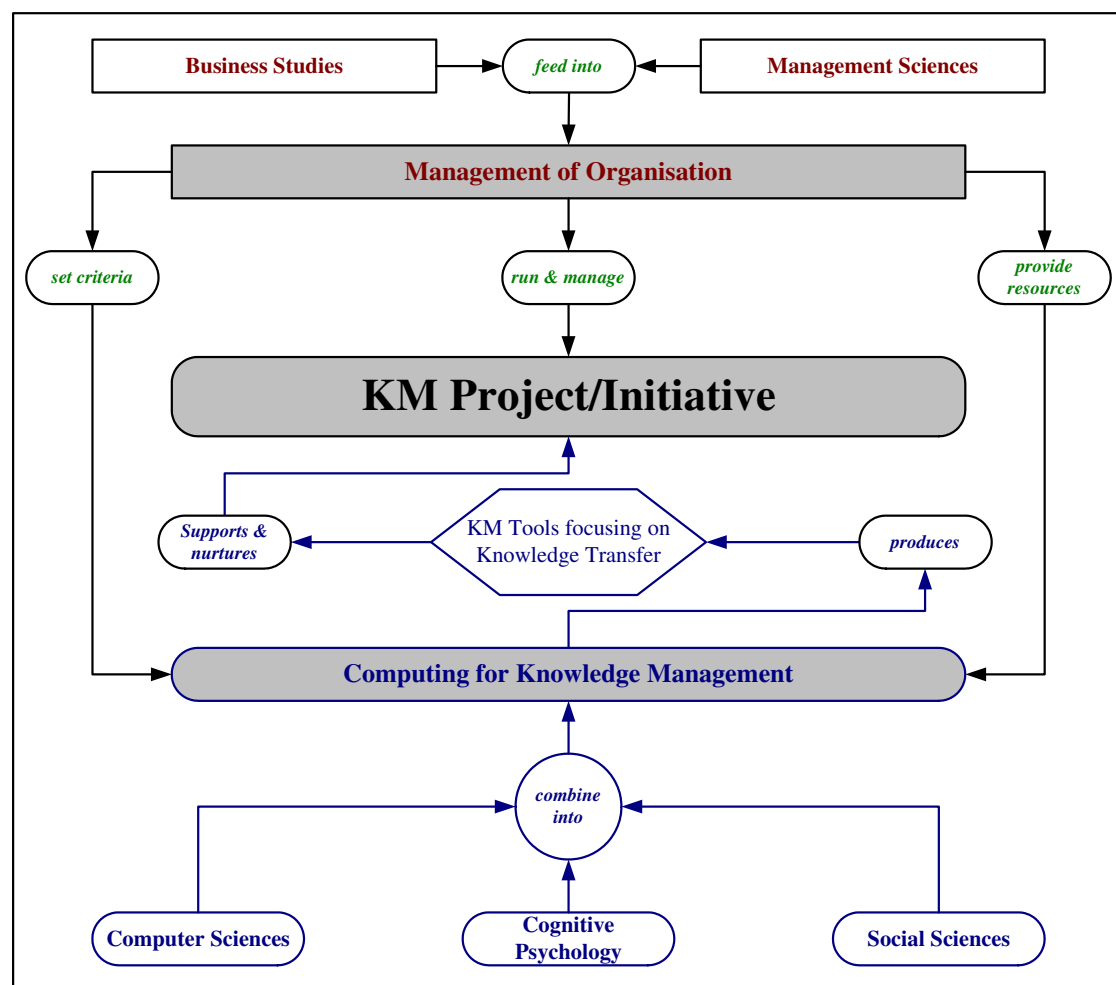
Figure 2. 22: Computing for KM

2.8.3 The Challenge of Knowledge Transfer

OKC is about mobilising, in other words transferring, the tacit knowledge held by individuals in the organisation (Nonaka, 1994). Knowledge transfer is not just another element of OKC and KM; it is the ultimate factor. Knowledge transfer is to OKC and KM what electrical power is to a ventilator.

Any Knowledge Management effort must cater for the conversion of tacit knowledge into explicit knowledge with the aim to allow the recipients of that explicit knowledge to internalise it (Nonaka, 1994). In order to allow for this, the knowledge in question must be made transferable and a mechanisms for the transfer needs to be established.

Keeping the *SPIRAL* turning in essence addresses the need for continuous knowledge transfer. The requirements for the successful knowledge transfer run exactly along the lines of those for OKC as illustrated in *Figure 2.23*.

After: Goh (2002) Figure 1 An integrated framework: factors influencing effective knowledge transfer
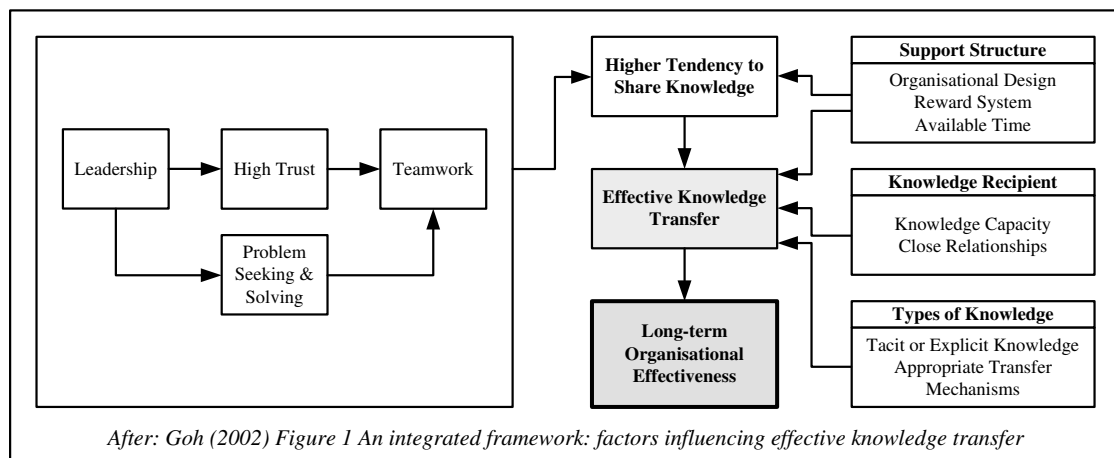
Figure 2. 23: Knowledge Transfer and the Organisation

It is obvious that no tool, no matter how excellent, can do the learning for the user. There are many variables that influence the outcome of communications. Clear and Kassabova (2008) argue that learning equates to the sharing of knowledge and that knowledge is located somewhere midpoint between personal experiences and abstractions. The transfer of knowledge, even under the best of circumstances, therefore is very hard to achieve (Liyanage *et al*., 2008) and success is never guaranteed as exemplified in *Figure 2 - 24*.
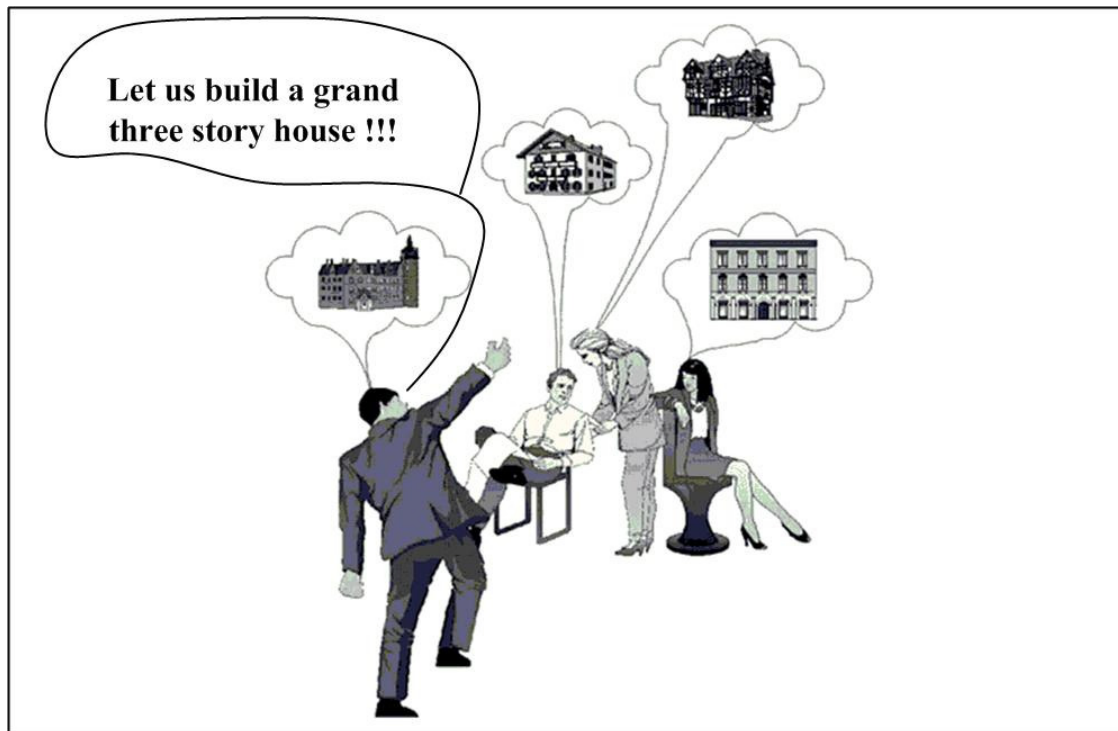
Figure 2. 24: Ambiguities in Communications

Albino *et al*. (2004) propose that

❑ The transfer of knowledge entails communications between humans

❑ Communications between humans in the transfer of knowledge can be mediated by technology

❑ It is human cognition that translates information into knowledge

❑ Machines are only able to handle data or information

The transfer of knowledge by electronic means features some striking similarities with electronic communications between machines. In fact, the former can be considered to be grounded on the latter (Albino *et al.*, 2004).

The use of the Shannon model of communications, (more commonly known as the Shannon-Weaver) as depicted in *Figure 2 - 25* therefore seems appropriate.

After: Shannon (1948) Fig. 1 - Schematic diagram of a general communication system. Page 2
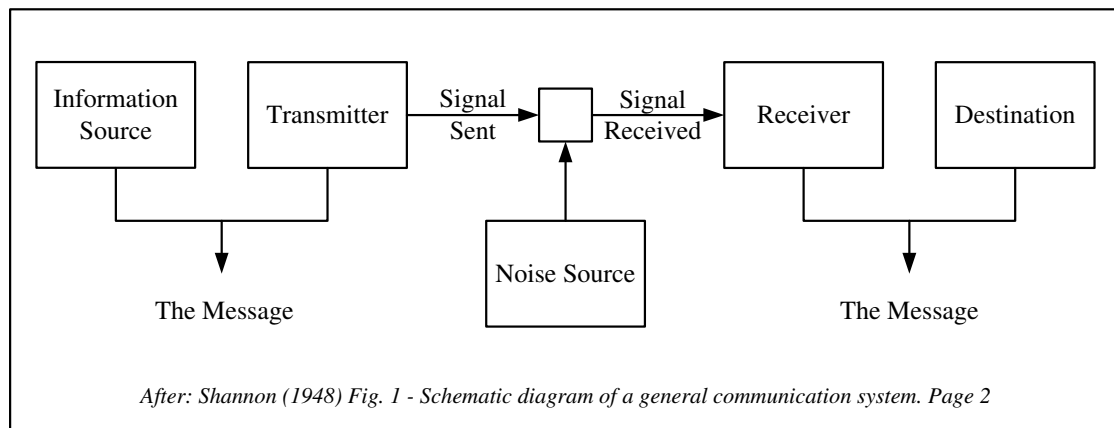
Figure 2. 25: The Shannon-Weaver Model of Communications

Any kind of communications between humans is of course far more complex that communications between machines. The issue of noise, however, is an issue common to both. Electronic engineers seek to attenuate noise in the transfer. KM technologists also need to focus on noise, or in the context of knowledge transfer, ambiguity. The transfer must be considered a failure if the mental picture of the source is not replicated precisely in the mind of the receiver.
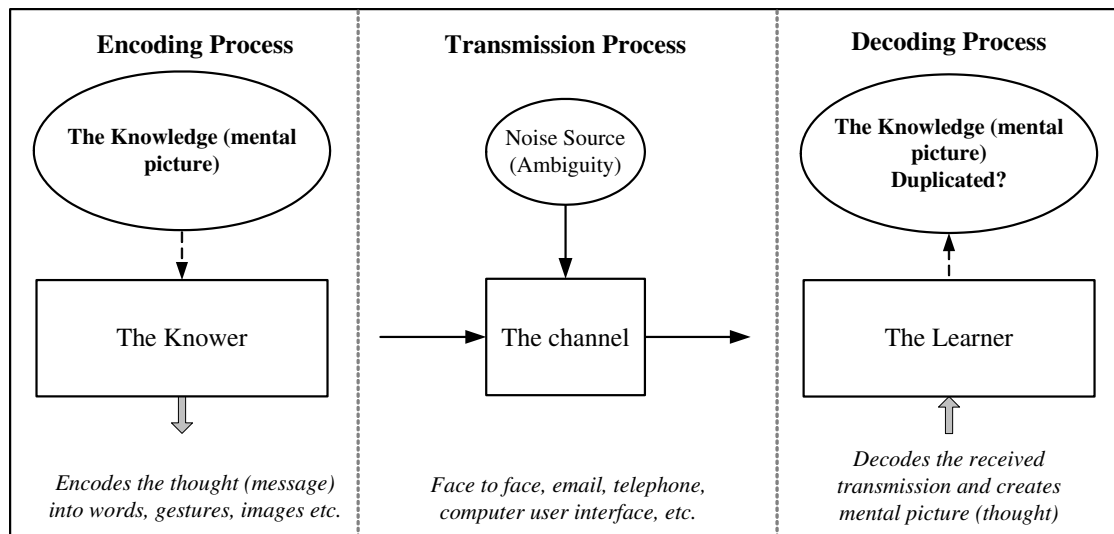
Figure 2. 26: A Basic Model of Knowledge Transfer

The transfer of explicit knowledge lends itself to be documented (Davenport and Prusak, 2000, p.95) by nature. The situation is very different with tacit knowledge. Davenport and Prusak (2000, p. xiv) contend that face-to-face interactions will always produce better results than communications mediated by technology. This is a very valid point that can hardly be disputed, however, the reliance on face-to-face

interactions is no longer a viable option for modern organisations (Utting and Yankelovich, 1989; Alavi and Leidner, 1999) of even medium size.

This poses a significant challenge to KM technologists. The presentation of knowledge by electronic means has some advantages but also serious drawbacks.

- ❑ Users can access and view the information or knowledge in their own time and at their own pace.
- ❑ But they cannot ask any probing questions, nor do they get immediate feedback.
- ❑ Undesirable ambiguity is always a potential problem.

If knowledge is to be transferred effectively, it must be in harmony with the existing social context. The knowledge contained within any organization is complex since it is based on individual interpretation, cognition and behaviour, which in turn shape contextual resources and rules (Guzman and Wilson, 2005). The success of technology therefore depends to a great extent on how it factors in cognitive processes, the cultural background and the aim of the transfer (Albino *et al.*, 2004). This is made more complex due to the increased mobility of individuals. The modern workforce throughout Ireland and the European Union is increasingly multi-national.

Tacit knowledge, as shown in section 2.4.3, is very difficult to externalise, however, it is not impossible (Nonaka, 1994) and considering the substantial value it represents it is a worthwhile effort (Davenport and Prusak, 2000, p. 81). Any true KM tool must take on the challenge of knowledge transfer not only of explicit but also of tacit knowledge.

The role of technology in knowledge transfer must be to support the cognitive processes of the user. The simple supply of the medium for information transmission as per Shannon's model is insufficient (Albino *et al*., 2004). This is precisely where KM tools can and must differ from Information Systems.

Cognitive Load Theory, as proposed by Sweller (1988) indicates improved problem solving performance if the individual's mental workload decreases (ibid; Sweller,

2004; Paas *et al.,* 2004). Such a decrease in the mental workload can be achieved through the visual representation of knowledge.

2.9 Conclusions

In this chapter it has been explained that there are clear reasons for the confusion that surrounds the field of KM and that much of this confusion can be resolved by drawing a clear distinction between KM and its underlying theory (OKC). Having established the required clarity, the role of computing for KM was scrutinized. Examining the current status of technologies deployed in KM it was found that currently there is no specific role for computing in KM. It has been shown, however, that there is the potential for KM technologists to find such a specific role through research that crosses disciplines by considering not only computer sciences but also cognitive psychology and sociology. Under that light the issue of knowledge transfer was determined to be the area that needs to be researched for the implementation of true KM tools. The following chapter will explain how existing research in the fields of visualisation and knowledge maps can be used to build the base from which true KM tools may be developed in the future.

3 VISUALISATION AND KNOWLEDGE MAPS

3.1 Introduction

Chapter Two explored OKC and KM with a focus on the functions that computing can perform in support of associated initiatives. It was found that KM technologists must focus on the transfer of knowledge if a distinct and specific role for computing is to be created. This chapter opens by explaining some specific challenges faced by the KM technologist in an environment where face-to-face contact as a means of communications is not always possible. The wider field of Visualisation is introduced as an area that may contain suitable solutions. The discussion then is moved on to the subset of knowledge visualisation since it is specifically concerned with the transfer of not only explicit but also tacit knowledge. Finally, existing research on several types of knowledge maps, themselves a subset of knowledge visualisation, will be examined. It will be shown why and how knowledge maps are an appropriate choice to facilitate the transfer of knowledge, supporting the user's cognitive processes and abilities.

3.2 An Overview on Visualisation

Visualisation is nothing new and has been used throughout human history. It supports human memory and helps individuals to handle tasks that are cognitively complex (Larkin and Simon, 1987). Whenever an individual draws a sketch or diagram to help another person to understand an idea or concept, that individual uses the principles of visualisation.

3.2.1 Visual Communication of Knowledge

In terms of computing it is important to realise that, regardless how efficient and sophisticated the technology in the background of any tool may be, all the user truly can perceive is the interface (Dillon *et al.*, 2005). The actual challenge therefore is the design of a human-centric (Carroll, 1997; Vail, 1999) visual transfer mechanism that delivers the information or knowledge in a cohesive, clear and effective manner (ibid; Dillon, *et al.*, 2005; Burkhard *et al.*, 2005) if it is to support the *SPIRAL*. It must not be forgotten that with any software project there is the possibility that the final product is a technological triumph but an organisational failure (Laudon and Laudon, 1999 p. 303; Masterton and Watt, 2000). This applies even more so to KM tools (Storey and Barnett, 2000).

Eppler (2005) raises the fact that many KM solutions do not focus sufficiently on the "*actual communication of knowledge.*" Yet the communication of knowledge is a key activity for the modern workforce (Eppler, 2004). Any KM tool therefore must take human-computer-interaction into account; otherwise it is not human-centric (Vail, 1999; Dignum, 2000) and therefore not consistent with OKC. Most applications used in KM deal with explicit knowledge only, thus forcing the user to already have contextual knowledge before s/he can handle the system (ibid). Such KM solutions that add to the workload tend to fail (Masterton and Watt, 2000; Davenport and Glaser, 2002). The choice of the means of presentation can have a considerable impact on the interpretation on part of the user (Bierstaker and Brody, 2001). Knowledge Visualisation offers a solution to these challenges and presents a methodical approach to knowledge transfer (Burkhard *et al.*, 2005; Eppler and Burkhard, 2007).

3.2.2 The Roots of Visualisation

Visualisation, as applied to the field of computing, exploits modern computing capacity and the fact that an estimated 50% of the human brain's neurons are dedicated to the processing of visual sensory input (McCormick *et al.*, 1987).

The science of interface design is a rather rich domain (Luo *et al.*, 1993). Visualisation therefore has a broad focus that spans a number of scientific fields and academic disciplines (Lohse, *et al.*, 1994) all exploiting the principles of visual perception (Börner *et al.*, 2003). Visualisation need not necessarily be very complex, even a table can be considered the first step of visualising information and knowledge (Eppler, 2006). Yet the tabular approach is not a very effective method since tables may lack in their richness of structure (Eppler, 2006) and thus may not be helpful in the discovery of elaborate concepts and new insights.

McCormick *et al.* (1987) elucidate that visualisation unifies the following mostly independent but converging sectors:

- ❑ *Computer graphics*
- ❑ *Image processing*
- ❑ *Computer vision*
- ❑ *Computer-aided design*
- ❑ *Signal processing*
- ❑ *User interface studies*

Precise definitions for visualisation vary depending on the individual application. In the context of KM the last item of the above listing is of most interest and visual representations are probably best defined as data structures utilized to express knowledge (Lohse, *et al.*, 1994).

It is not by accident, Blackwell (2006) explains, that interface design studies resemble cognitive educational theory, since cognitive theories on education had fundamental influence on HCI related research in the 1970's. Interface design studies obviously

must be based on sound scientific understanding (Lohse, 1991) and indeed are based on cognitive psychology (Carroll, 1997; Patel and Kushniruk, 1998; Hasan, 1999; Blackwell, 2006).

Carroll (1997) considers the field of Human-Computer Interaction (HCI) to reside at the intersection of the social sciences and psychology on one side and technology and computer science on the other as illustrated in *Figure 3.1*. HCI endeavours to understand human beings in terms of how they interact with technology, thereby aiming to support the user (ibid). As such it is a science of design.
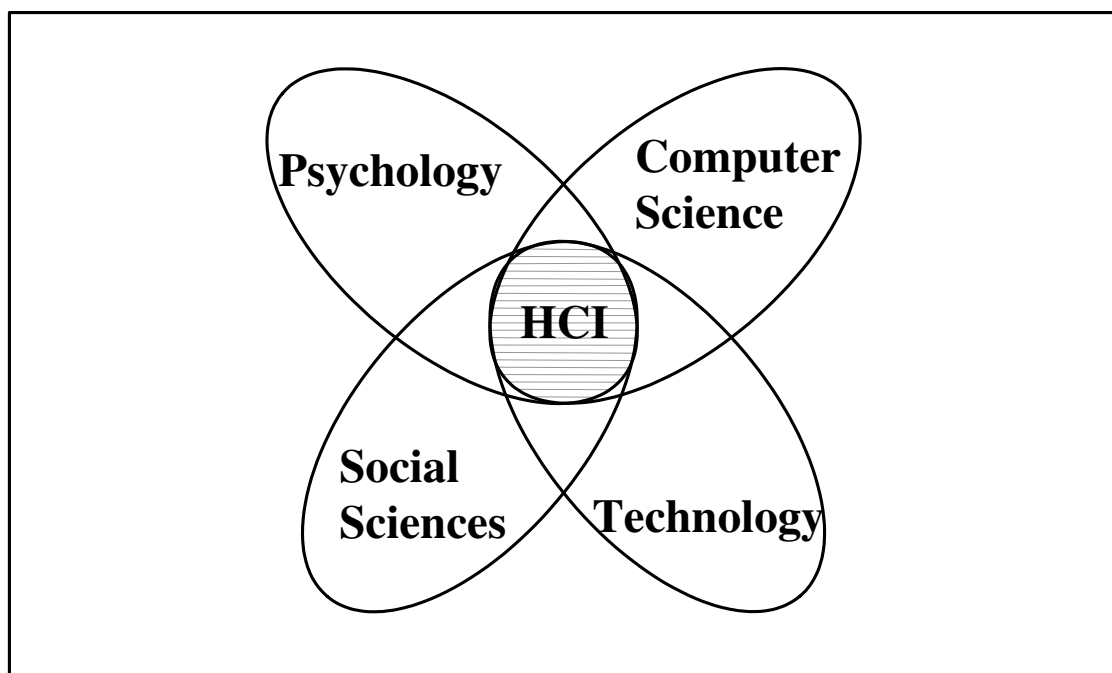
Figure 3. 1: Roots of HCI

Allan Paivio proposed the *Dual Coding Theory* in the 1960s and refined it ever since (Najjar, 1995). The theory provides an important foundation to the application of visualisation. It describes the activities of two distinct subsystems of human cognition. The first, the verbal system, specialises in dealing with language directly and the second, the nonverbal system, specialises in dealing with objects and events of a non-linguistic (images) nature (Paivio, 2006).

These systems are considered to be composed of ***logogens*** and ***imagens*** (internal representational units) that are activated during recognition, manipulation, or just thinking about things or words (ibid) as illustrated in *Figure 3.2* below.
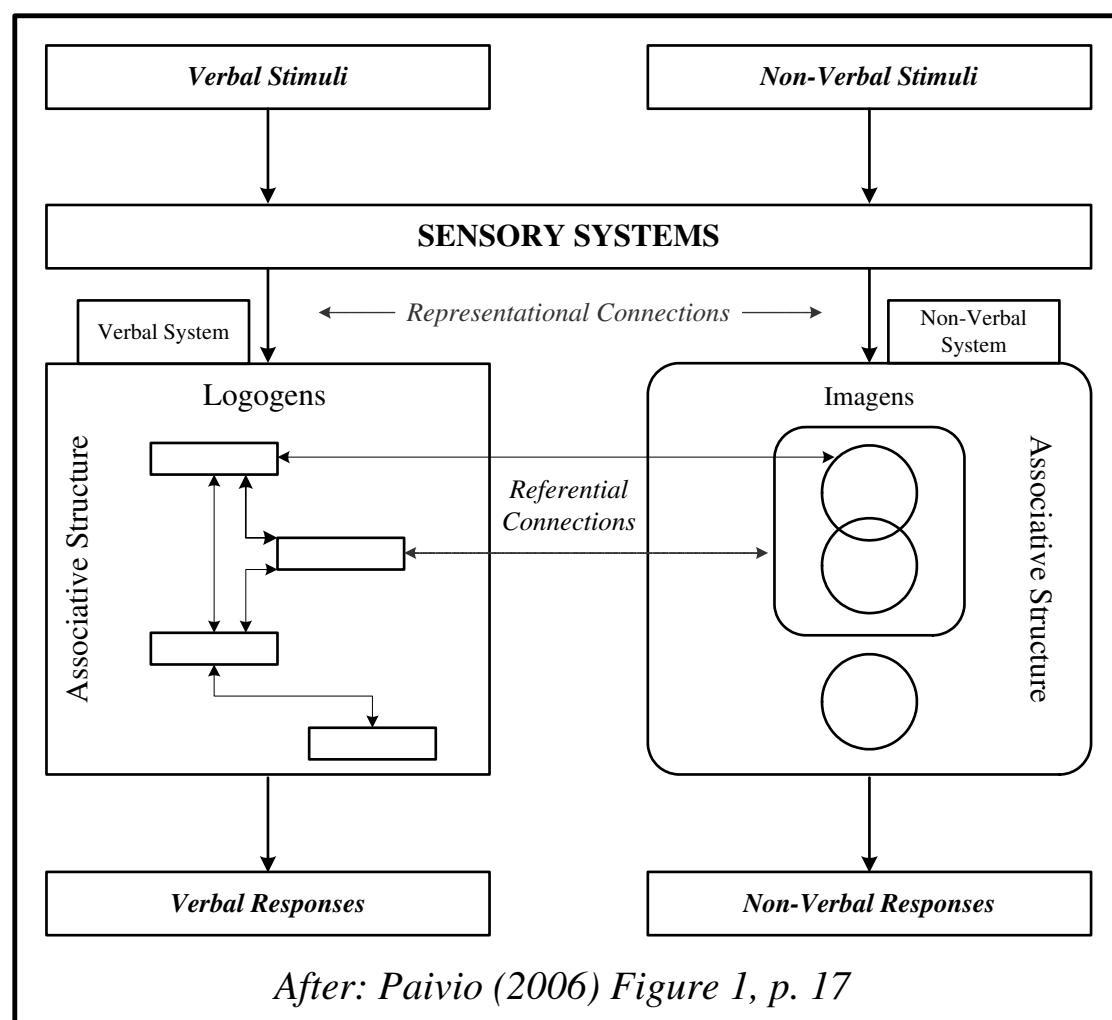
Figure 3. 2: Paivio's Cognitive Coding Systems

Tangible objects and/or terms are being encoded twice in the brain's memory, verbal and non-verbal; Abstract terms like for instance justice are only encoded in the non-verbal system. It therefore is much harder to retain text only (Paivio, 2006).

For that reason Zimbardo and Gerring (1999, p. 292) call for the graphical representation of information whenever possible. Research shows clearly that the difference in outcomes between tangible, graphic learning material and purely abstract learning material can be ascribed to that dual encoding in the brain. This issue is of greatest importance to the KM technologist.

Information Foraging Theory (ACT-IF) as proposed by Pirolli and Card (1999) teaches that the user or forager is indeed concerned with the relationship between the effort required and the usefulness or profitability of the return. Anderson and Milson (1989), investigating the issue of statistics in information presentation explain the principle of the *Optimization Problem*.

$$\mathbf{p[A]G < C}$$

where

p[A]   =   *The probability of finding the desired target*
G   =   *The potential gain from finding the target*
C   =   *The cost of finding the target*

It describes in essence that a system like the human memory will only search for a piece of information for as long as the potential gain outweighs the cost. This principle can and must be applied to any tool that is designed to support the transfer of knowledge. The user will only expend effort for as long as the cost is smaller than the potential gain (Pirolli and Card, 1999; Masterton and Watt, 2000; Markus *et al.*, 2002). The larger and more unwieldy the tool or type of information presentation, the earlier that point will be reached.

Miller (1956) found that, the capacity of humans to process information is limited; only seven plus/minus two chunks of information can be processed at any given time.

These are all issues that the KM technologist must keep in mind when tasked to design any tool that is to display information or knowledge with the aim of facilitating the transfer of that knowledge.

3.3 Metaphor and Ambiguity in Visualisation

Visualisation can be seen to aim at helping others and one self to better understand concepts and ideas. It therefore seems to make good sense to use metaphors.

3.3.1 Metaphor in Visualisation

Already Aristotle considered metaphor as the tool of cognition (Eppler and Burkhard, 2007). The use or metaphor can be exceedingly helpful in making tacit knowledge explicit (Eppler, 2001). The term metaphor is rooted in the Greek word *Metaphora*, which best translates into "*meaning transportation*" (Suárez *et al.*, 2004). The Collins Modern English Dictionary (1990) describes metaphor as follows:

> "*A figure of speech in which a word or phrase is applied to an object or action that it does not literally denote in order to imply a resemblance, for example 'he is a lion in battle'* " (p. 531)

A metaphor therefore can be described as a transportation of meaning from one domain to another (Suárez *et al.*, 2004) where a number of inferences are associated with both, the source and the target domain. Eppler and Burkhard (2007) exemplify this expertly, as illustrated in *Figure 3.3*, by using the metaphor of a bridge or bridging to the process of compromising.

Source: Eppler and Burkhard (2007) Figure 5:
A visual metaphor that outlines procedural knowledge on negotiation, p. 117
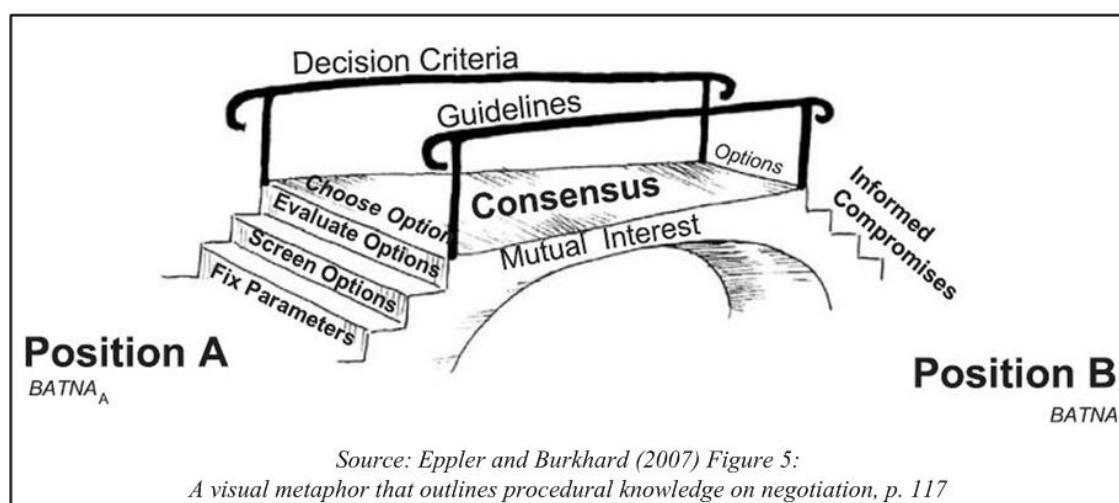
Figure 3. 3: Use of Metaphor in Visualisation

However, Blackwell (2006) urges caution and makes the point that an over reliance on metaphor can even be seen as harmful. Rogers and Osborne (1987) call for great care and consideration when it comes to the choice of images used to exemplify a concept. The associative chain of the designer may be very different from that of the user. A very well known metaphor is the one of the dashboard. Information about Key Performance Indicators retrieved from large stores of mostly transactional data is displayed on a computer screen based on the individual elements found on the dashboard or a regular automobile (Chowdhary *et al.*, 2006) This aims for the swift and easy interpretation of information (ibid). This type of data or information visualisation is used as a front end mostly in Business Intelligence (Few, 2005) and Executive Information Systems (Liang and Miranda, 2001). The intended target audience are generally senior managers and executives (Chowdhary *et al.*, 2006; Liang and Miranda, 2001). This metaphor, in Few's (2005) opinion, is one that can and has been taken too far as illustrated in *Figure 3.4*. This example clearly does not provide any support to the human cognitive processes.

Source: Few (2005) Figure 1: Re-Creation of Dashboard Gauges from Infommersion
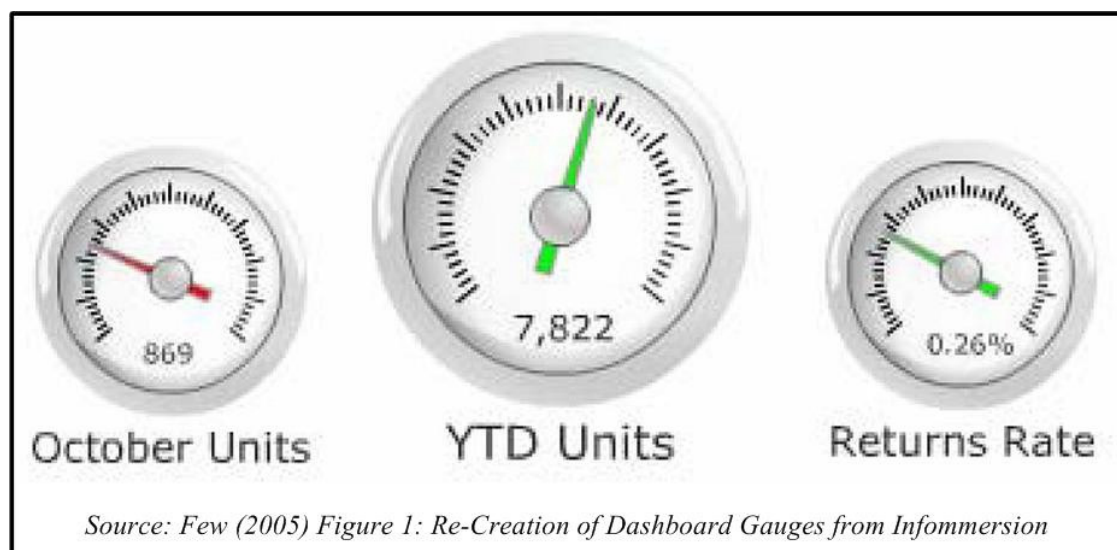
Figure 3. 4: Example of Poor Dashboard Visualisation

3.3.2 Ambiguity

The use of metaphor does indeed carry the risk of ambiguity and therefore misinterpretation (Rogers and Osborne, 1987; Eppler, 2003; Eppler *et al.*, 2008). Yet,

if applied with great care and consideration, metaphor can support the cognitive processes of the viewer and thus aid knowledge transfer (Eppler *et al.*, 2008). In order to avoid it or to make deliberate use of it, Eppler *et al.*, (2008) propose the classification of visual ambiguity as per *Figure 3.5*. This classification was predominantly made for the use during synchronous communications (ibid). However, the classification is also very valuable for asynchronous communications, since the impact of ambiguity there is much more severe and misunderstandings cannot be cleared up on the spot, thus having a negative impact on the transfer of knowledge.

After: Eppler et al. (2008) Figure 3: Categorization of visual ambiguity in group contexts, p. 394
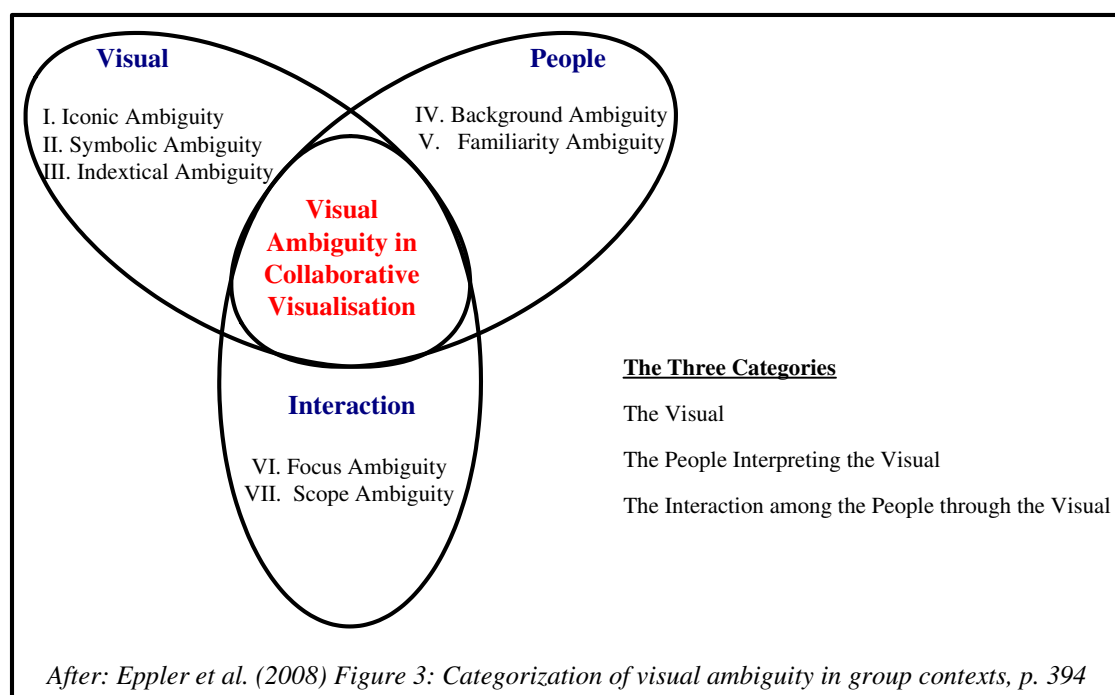
Figure 3. 5: Seven Types of Ambiguity

❑ **Iconic Ambiguity (Type I)**

Visual images referring to their content through likeness or resemblance are open to interpretation (ibid).

❑ **Symbolic Ambiguity (Type II)**

Generally agreed conventions may be the basis for visual images, however, these conventions may not be known to all involved (ibid).

❑ **Indexical Ambiguity (Type III)**

Visual images may be open to interpretation since they take their meaning from objects they point to in the exact context they are used in (ibid).

❑ **Background Ambiguity (Type IV)**

Visual images may be interpreted differently based on varying professional or cultural backgrounds (ibid).

❑ **Familiarity Ambiguity (Type V)**

The interpretation of visual images may depend on a specific level of familiarity with that image or type of image (ibid).

❑ **Focus Ambiguity (Type VI)**

Visual images may be interpreted differently depending on which part or element of the image the viewer focuses on (ibid).

❑ **Scope Ambiguity (Type VII)**

The interpretation of a visual image may depend on the exact understanding of what purpose it serves (ibid).

3.4 Two Major Groups of Visualisation

A distinction needs to be made between the visualisation of information or data and the visualisation of knowledge. The former is a mature field (Cañas, *et al.*, 2005) that has been studied extensively while the latter is a rather new field of scientific inquiry (ibid, Burkhard and Meier, 2005; Eppler and Burkhard, 2007). In terms of its application, Bresciani *et al.* (2008), generalise the difference between Information and Knowledge

Visualisation as illustrated in *Figure 3.6*, but make it explicit that there is a considerable intersection and a strict delineation is often not easy.
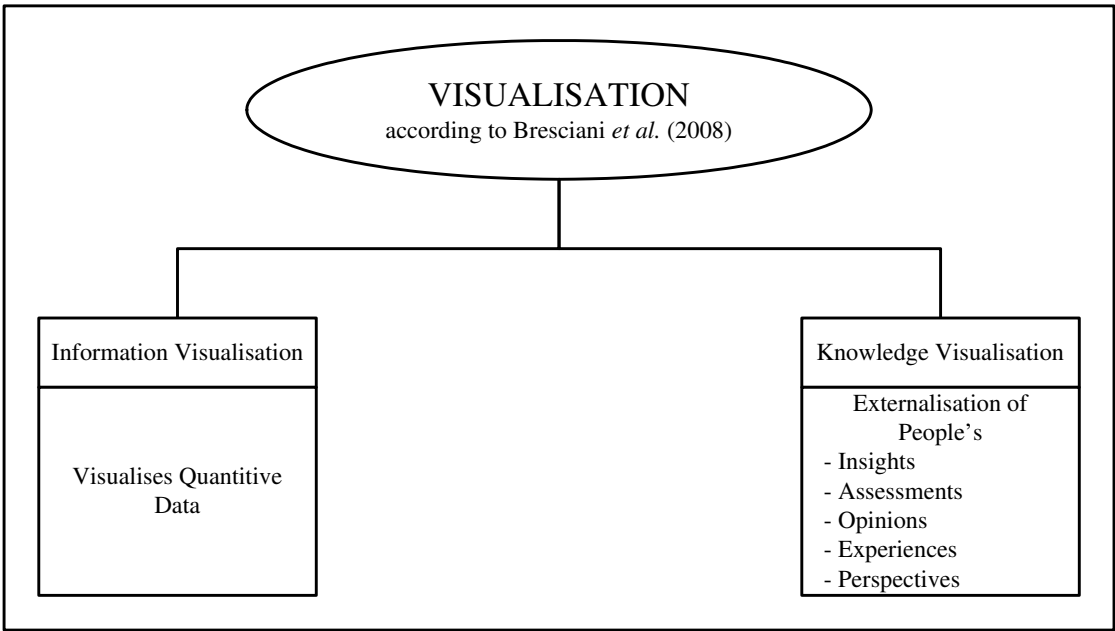
Figure 3. 6: Information v Knowledge Visualisation I

Approaching the issue from a slightly different angle, Burkhard (2004) differentiates as illustrated in *Figure 3 .7* below.
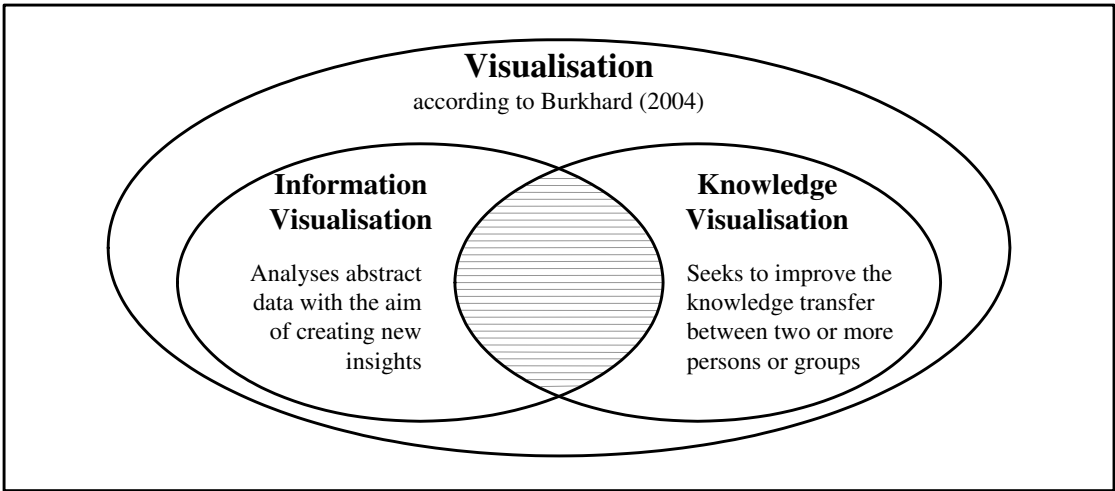
Figure 3. 7: Information v Knowledge Visualisation II

3.4.1 Information or Data Visualisation

Information or data visualisation aims for "*information perceptualization*" (Card, 1996) in terms of large data volumes and thus enhances a human's interaction with and the sense making of those large data volumes. As such it is not in line with the spirit of OKC. The whole field is probably best categorised on a sliding scale.

An excellent example of information visualisation can be found in the work of Börner, *et al.* (2003) who researched research itself. *Figure 3.8* exemplifies their work very well. It may be seen to be located at the more extreme end of its category. It will take an expert to extract any meaning from it.

An overview of the document co-citation map of 394 articles with 10 or more citations. In this network, a number of tight clusters of documents are connected to an artery-like chain. Documents on the artery chain tend to be seminal works of connected clusters. For example, Diana Crane's Invisible College (Crane, 1972) connects the scholar communication cluster to the artery chain.

Source (Image and Text): Börner et al. (2003) Figure 6, p. 34

Figure 3. 8: Example for Information/Data Visualisation

3.4.1.1 Tag Clouds

Tag Clouds are another example of information/data visualisation. However, they move more to the softer side on the sliding scale. Tag clouds visually display a group of words (tags) from a piece of text, where the appearance of the individual words depends on relevant properties of each individual word (Schrammel *et al.*, 2009). The most commonly used property is the number of occurrences of a word within the source text. The more often a word appears within the text, the more prominently it will be displayed within the tag cloud.

This form of data/information visualisation can for instance be used by an author to check on the actual message that is actually passed on (Gordon and Lawless, 2009). Unlike the image seen in Figure 3.8, a tag cloud will carry some semantic meaning even to the non-expert or somebody else than the author of the text that has been visualised. *Figure 3.9* shows a tag cloud created using the full text of chapter 2 of this dissertation.

Image created using: http://www.wordle.net/
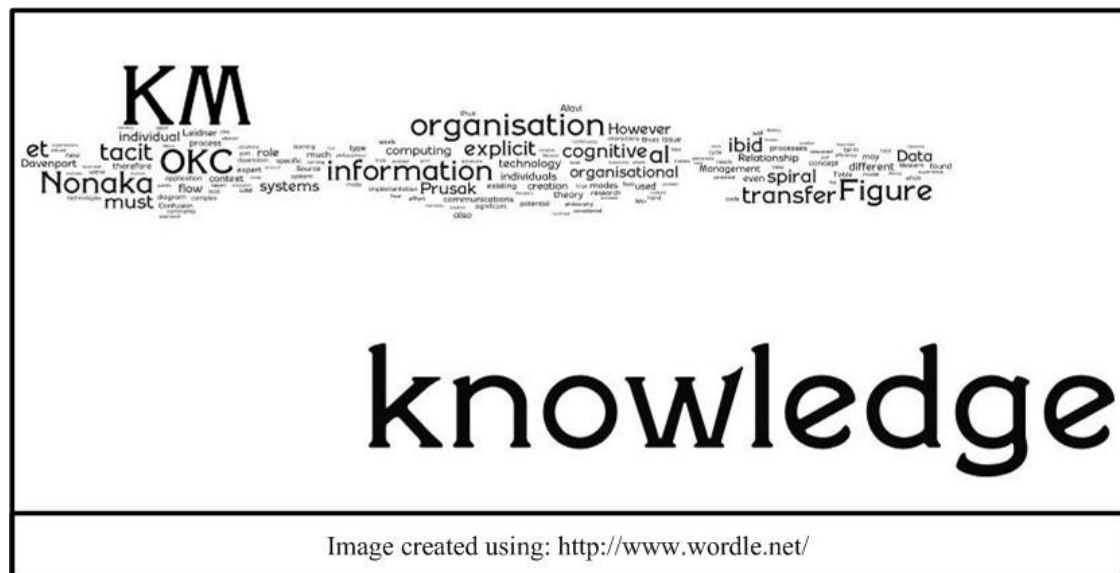
Figure 3. 9: Tag Cloud I

For the creation of the tag cloud in *Figure 3.10*, the word '**knowledge**' was removed. The remaining words are now able to take on more prominent position thus giving the viewer an even better feel for the nature of the content. For the creation of the tag cloud in *Figure 3.11*, the term '**KM**' was removed for the same reasons as before.

Image created using: http://www.wordle.net/

Figure 3. 10: Tag Cloud II

Image created using: http://www.wordle.net/

Figure 3. 11: Tag Cloud III

3.4.1.2   G*Power

The software tool **G*Power** (Erdfelder, Faul & Buchner, 1996) exemplifies another type of information visualisation. The tool can be used for power testing (calculating the required sample size given a particular confidence level) and also offers an extensive range of exact statistical tests (*Faul et al.,* 2007). It is available (http://www.psycho.uni-duesseldorf.de/abteilungen/aap/gpower3) at no cost. *Figure 3.12* visualises the probability of alpha and beta errors under the specified

circumstances. This type of visualisation must still be classed as information visualisation. However, it is even further away from the extreme end of its category. The visualisation uses encoded expert knowledge to make it easier to understand the issues involved even for those who have a lesser background in advanced statistics. In itself it does not drive the *SPIRAL*, however, the knowledge of experts is applied for the benefit of the user. It might be said that, in a sense, some form of knowledge transfer is already taking place.
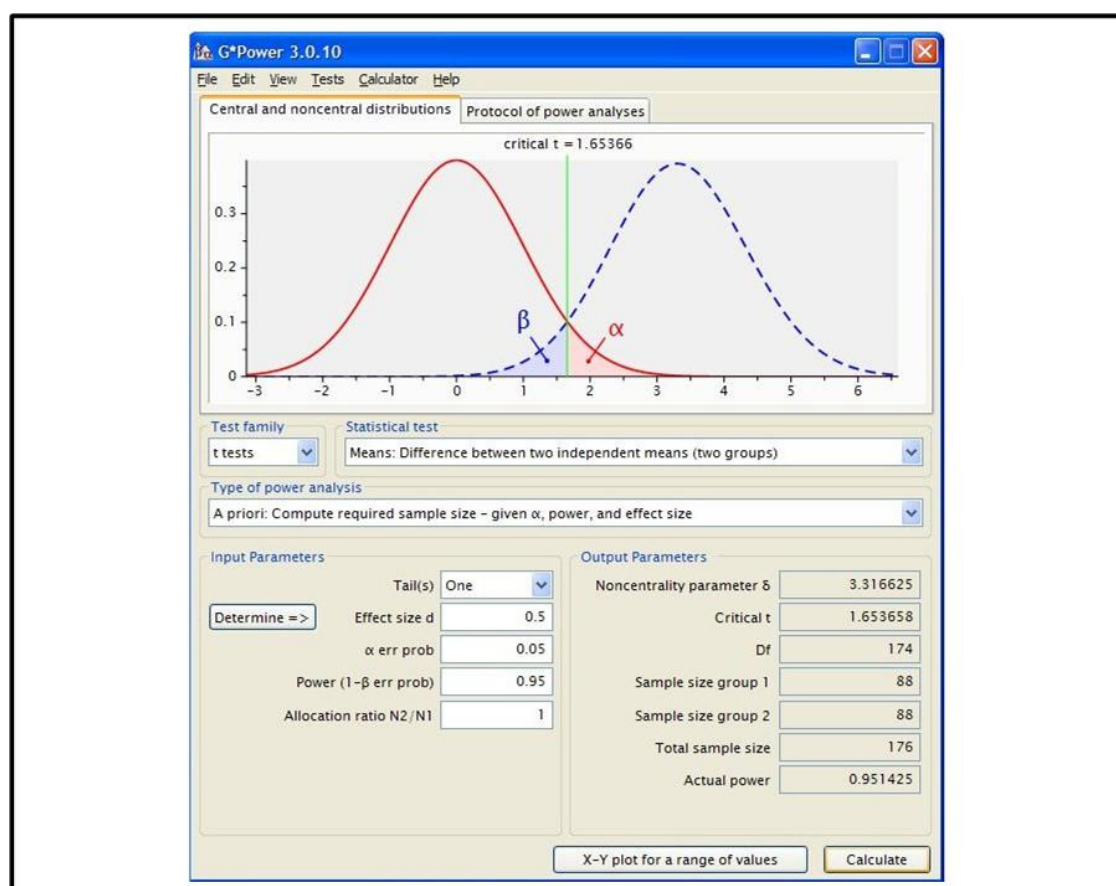
Figure 3. 12: G*Power Screen Shot

Through the use of the tool, the non-expert is enabled to do something s/he could not or not do so easily before. This nearly satisfies the definition of knowledge as presented in Section 2.4.1. It doesn't quite fulfil the criteria of OKC and the *SPIRAL*; however, this form of visualisation does support the *COMBINATION* and *INTERNALISATION* quadrants of the SECI model.

3.4.2 Knowledge Visualisation

Knowledge Visualisation has a completely different focus compared to information/data visualisation and is probably best demonstrated in extreme simplification by comparing the sentence below to *Figure 3.13*.

❑ This dissertation is part of the MSc in Computing (Knowledge Management) course administered by the School of Computing of the Faculty of Science within the Dublin Institute of Technology.
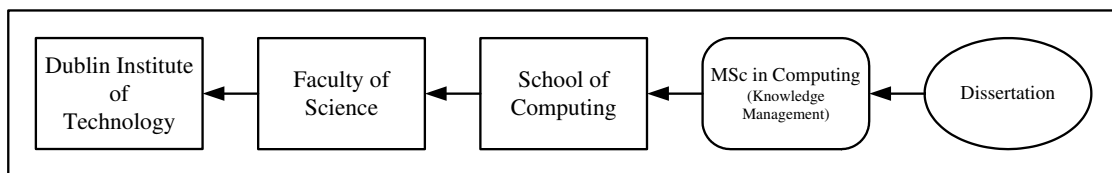
Figure 3. 13: Dissertation Context

Knowledge visualisation requires considerable deliberations before the design process can even begin. Burkhard (2005) proposes four different perspectives to be considered whenever visualisations with the aim of knowledge transfer are created. The goal, the knowledge type, the target group and best method of visualisation must be considered (ibid) as illustrated in *Figure 3.14*.

Reproduced from Source: Burkhard (2005) Fig.1, Page 529
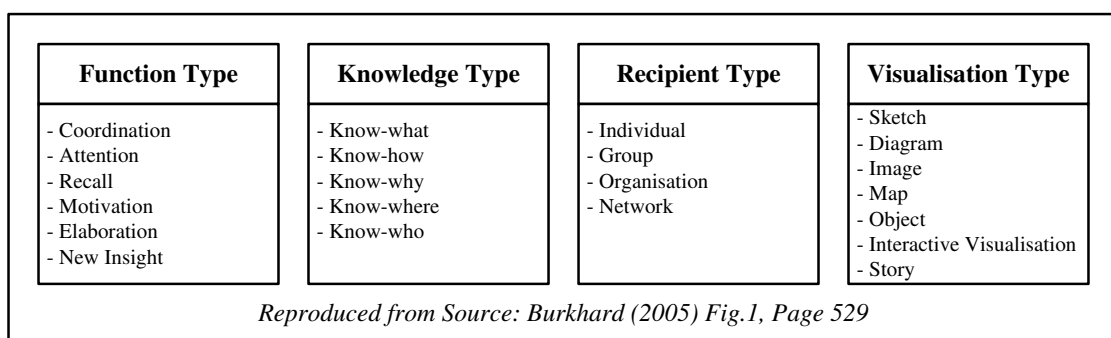
Figure 3. 14: Visualisation Perspectives

It appears appropriate to continue the discussion with the presentation of a case study documenting a successful implementation of knowledge visualisation.

3.4.2.1   A Case Study on Knowledge Visualisation

Burkhard and Meier (2005) managed to resolve an unsatisfactory situation in an organisation through the innovative use of knowledge visualisation. This case study narrates sections of the publication "*Tube Map Visualization: Evaluation of a Novel Knowledge Visualization Application for the Transfer of Knowledge in Long-Term Projects*" by Burkhard and Meier (2005). Comments on the narration are highlighted by the use of `Courier New (10)` font.

3.4.2.1.1   The Challenge

An organisation operating in a very specialised field was running a significant long-term project aiming to implement a quality development process. Involvement and engagement of the individual staff member was of paramount importance. The project, however, was impaired by a lack of engagement on the part of the staff. Traditional approaches like project plans, emails and flyers failed to get sufficient attention. Any approach provided either too much or too little detail. Staff members were not motivated to take the required actions at the desired time. The fact that individuals were not taking action indicates that the traditional methods deployed in this specific case did not manage to transfer the required knowledge. In order to rectify the situation Burkhard and Meier had to overcome three major challenges:

❑ Knowledge Transfer: *The individual must be enabled to easily grasp the meaning and its implications of the information presented.*

❑ Interfunctional Communications: *Wording and layout must appeal to people in very different roles with diverse preferences and information needs.*

❑ Information Overload: *Regardless of the nature of the organisation, individuals are bombarded with information. Ways must be found to balance between the needs for overview and detail.*

3.4.2.1.2 The Solution

Burkhard and Meier employed the method of metaphor. After considering several options they settled on the metaphor of the Tube Map, seemingly based on the maps displayed within the London Underground system. An example of the map can bee found in *Figure 3.15*.

An enlarged element of the map is depicted in *Figure 3.16*. The map was designed and initially created on a computer, however, Burkhart and Meier decided on a manual implementation. It was agreed that a manual implementation would provide greater aesthetic value, which was considered to be of the utmost importance under the specific circumstances. Updating the posters manually added to the workload, however, this was considered an acceptable trade-off.

Burkhard and Meier considered the target audience for the visualisation effort and selected the Tube map metaphor for the following reasons.

- For its implication of a complex and dynamic system where unforeseeable occurrences may happen.
- The underground system helps individuals to get to their targets.
- The map appeals and fascinates urban people.
- The map provides overview as well as detail in one single image.
- It gives structures to the information and allows the viewer to take a closer look at the details if that is required.

The map was organised in the following fashion.

- The map represented the whole project.
- Each tube line represented a target group.
- Each station represented a milestone, both individual and collective.

The map, after a careful and iterative design process was placed in strategic places on the premises of the organisation as illustrated in *Figure 3.17*.

Source: Burkhard and Meier (2005) Figure 4, p. 486

Figure 3. 15: The Tube Map

Source: Burkhard and Meier (2005) Figure 5, p. 486
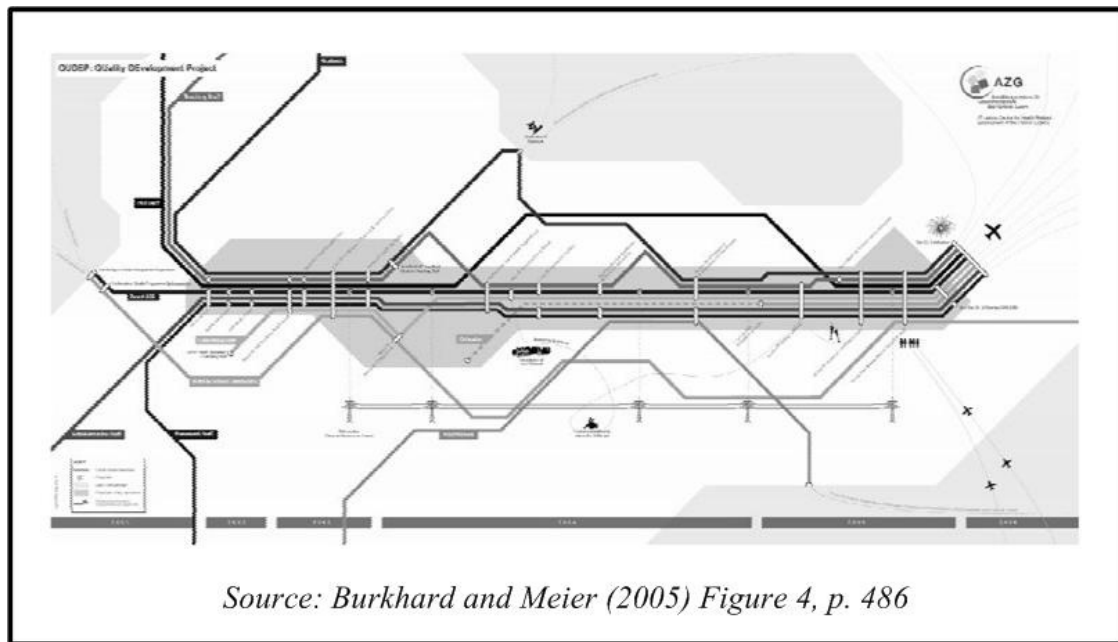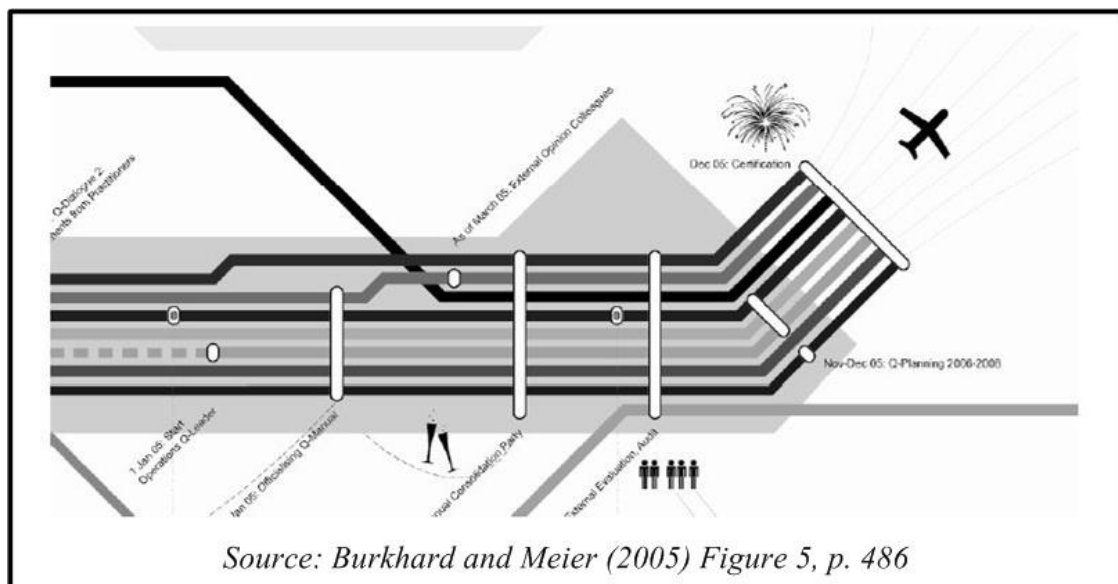
Figure 3. 16: Tube Map Zoom-In

Source: Burkhard and Meier (2005) Figure 6, p. 487
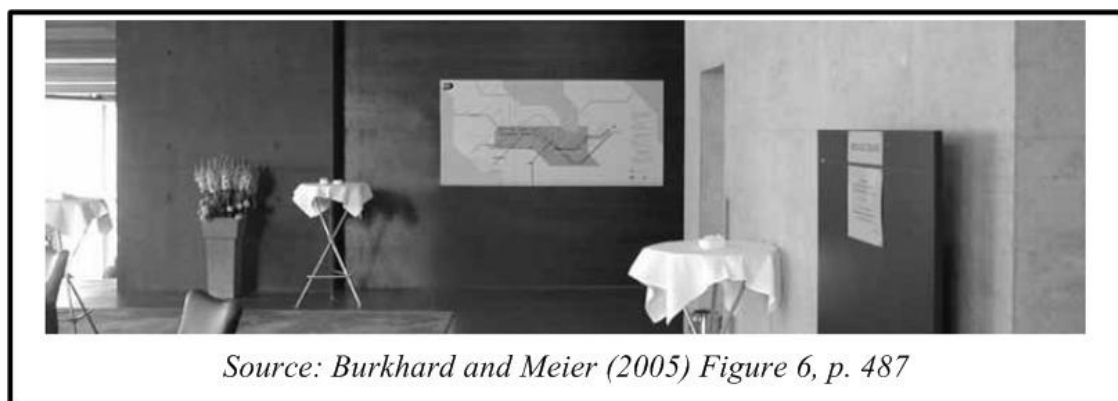
Figure 3. 17: Tube Map on Display

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3.4.2.1.3 Audience Reception and Results

Burkhard and Meier report that the solution was received very positively. The decision was made to evaluate the success of the initiative in a formal manner. Two months after the maps had been made public in various locations, a paper-based anonymous questionnaire of 14 questions was passed out to the staff. Out of the 81 staff members, 45 returned the questionnaire, a response rate of 56%. The results indicate that the initiative can be regarded as a success. Motivation and interest replaced the previously dominant sentiment of uncertainty among the staff members. They received written notes stating, that the Tube Map Visualisation provided orientation and allowed staff members to get a grasp of the whole project.

Source: Burkhard and Meier (2005) Figure 7, p. 489
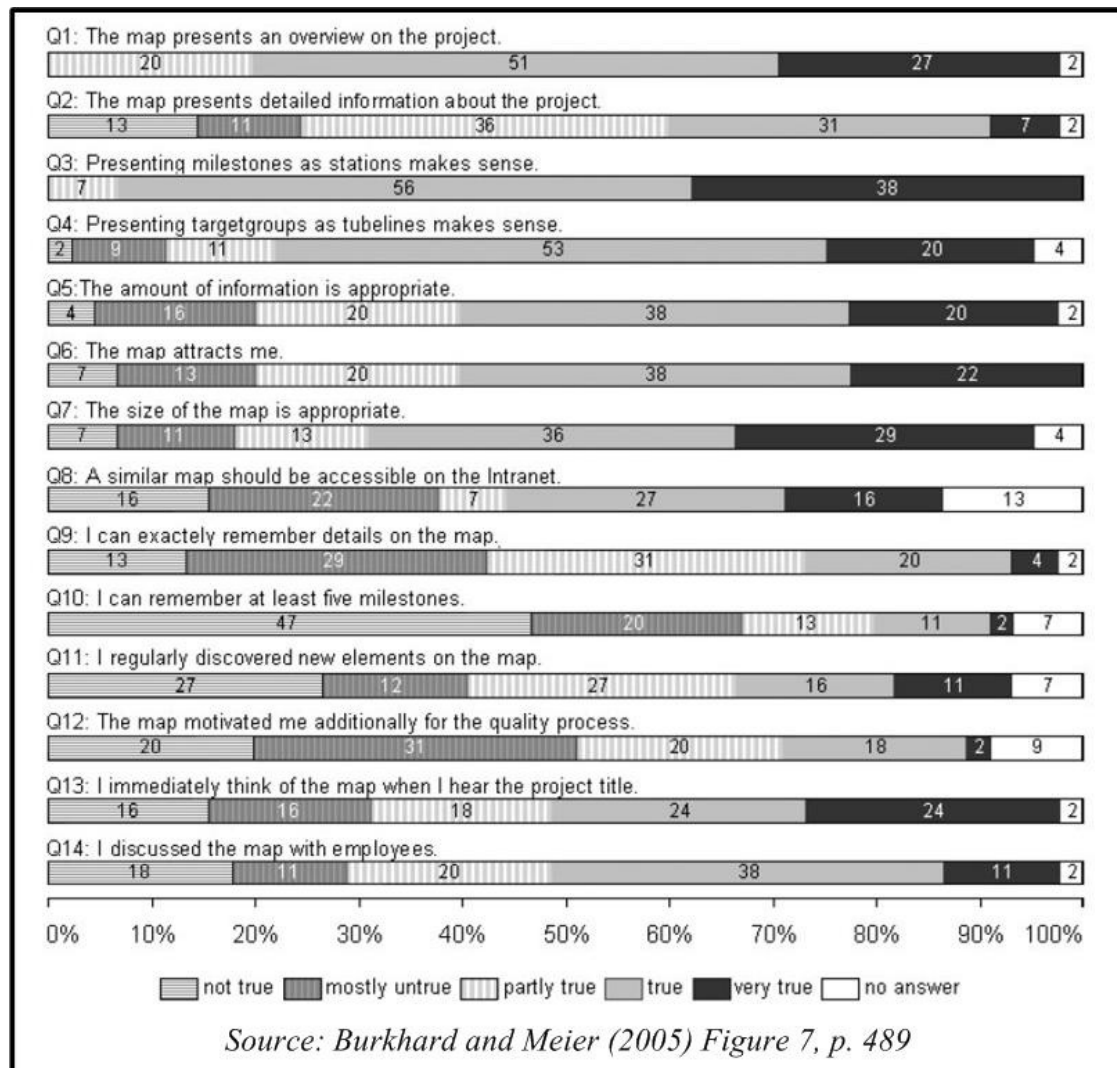
Figure 3. 18: Results Evaluation

An overwhelming majority agreed to the statements made in questions 3 (Presenting milestones as stations makes sense) and 4 (Presenting target groups as tube lines makes sense). `This may be seen as a first indicator of staff having been brought on board.` Over 50% agreed to the statement (Question 5) that the amount of detail presented in the map was appropriate. Burkhard and Meier report that the map had motivated individuals to seek further information that was not displayed on the map. `This may indicate that individuals had begun to 'combinate' as per Nonaka's OKC.` More than 50% agreed that they were thinking of the map when they heard about the project (Question 13). Also over 50% stated that they had discussed the map with fellow staff members (Question 14). `The results for the last two questions may indicate that, the knowledge encoded in the map was in the progress of being socialised, internalised and potentially externalised as per Nonaka's OKC. With that, all components were in place for the SPIRAL to start turning.`

`The success of this effort by Burkhard and Meier may indicate that the approach of visualisation is viable and practical and can be deployed for technical implementations as well.`

`The fact that the implementation of the visualisation was not published in a technical way does not invalidate the experience for the purpose of this dissertation. Existing, even wireless, billboard technology for instance is a viable option (Te-Kai et al., 2004) and sufficiently sophisticated (Haritaoglu and Flickner, 2001; Paulson, 2005) to be deployed in situations similar to the one described in this case study.`

3.4.2.2   The Nature of Knowledge Visualisation

Saad and Zaghloul (2002) consider knowledge visualisation to reside at the junction of cognitive science, graphic design and information graphics (*Figure 3.19*).
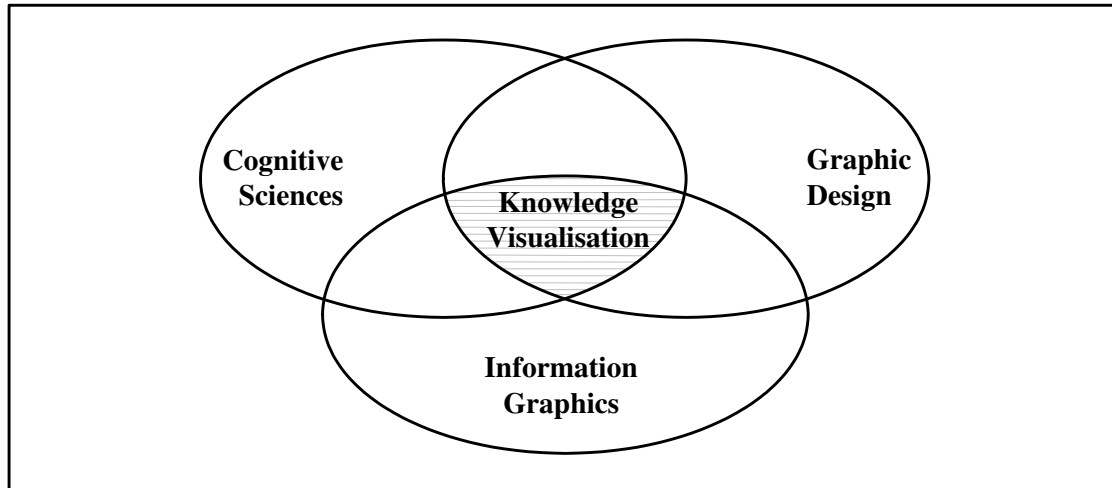
Figure 3. 19: Roots of Knowledge Visualisation

Nonaka (1998, p. 31) makes the point that to convert tacit knowledge into explicit is an endeavour to express that which cannot be expressed. Knowledge visualisation goes a long way to achieve the seemingly impossible (Burkhard and Meier, 2005). Knowledge Visualisation can be described as to appraise visual representations in their use of improving the knowledge transfer between "*at least two persons or groups of persons*" (Burkhard, 2004). It can be particularly helpful to integrate knowledge in cases where the topic is very complex (Mengis and Eppler, 2006). Knowledge visualisation supports all of the *SPIRAL's* sub-sections in the ontological dimension, that is to say it can be deployed at the "*personal, interpersonal, team, organisational, inter-organisational and societal*" (Eppler and Burkhard, 2007) levels. The same applies to the epistemological dimension of the *SPIRAL*. Here finely tuned nuances of explicit and tacit knowledge, ranging from straightforward facts to experiences and insights (ibid) can be represented. Research undertaken by McCall *et al*. (2008) finds that users show larger improvement in their interpretative skill of problem solving if they are provided with visually orientated KM tools. The same applies to the retention of information presented (Hall, *et al.*, 2002). These research results are in line with *Cognitive Load Theory* (Sweller, 1988). While no exhaustive list can be created, the

only limit is the imagination of the individual, Eppler and Burkhard (2007) propose the knowledge visualisation techniques as illustrated in *Figure 3.20* as representative of the field. Some graphic examples will be provided in section 3.5.
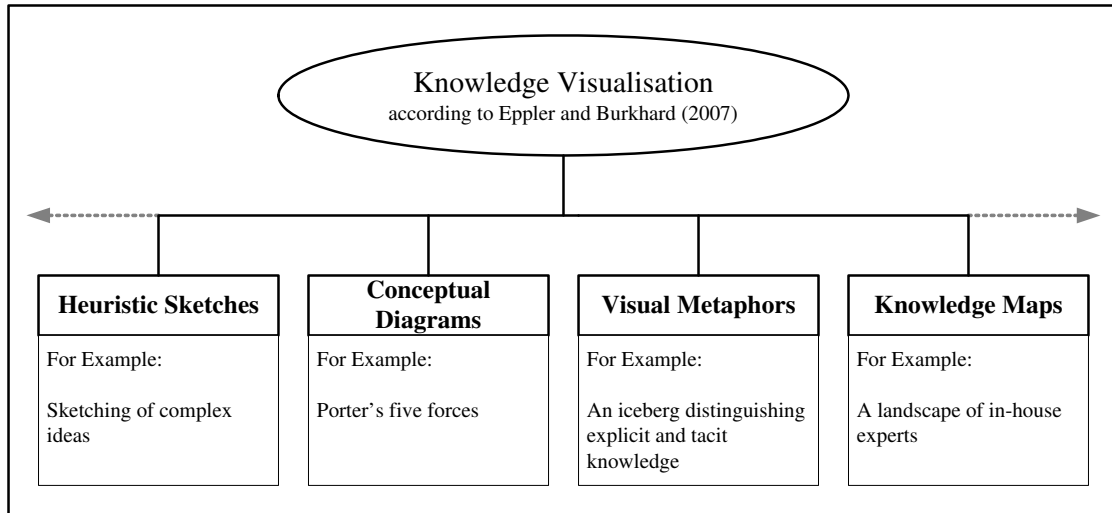
Figure 3. 20: Knowledge Visualisation

Saad and Zaghloul (2002) find that, once individuals have mastered the fundamental basics of any field they are ready to apply it to many learning contexts. Knowledge visualisation can help to create that basic common ground or shared context as stipulated by Nonaka (1994). If one is to achieve mastery of any field of knowledge, learners must be actively encouraged to construct their own knowledge base. Knowledge visualisation allows for this in a step-by-step fashion (Saad and Zaghloul, 2002). It of course is indispensable for the interface designer to understand the intended target audience or user group (Blackwell, 2006; Burkhard, 2004). Only if the designer understands how individuals work, learn, think perceive and interact can s/he produce truly human-centric tools (Hasan, 1999; Allee, 2001; Sharples *et al.*, 2002) such as are required to keep the *SPIRAL* going.

Knowing all aspects of the targeted audience, however, is not always possible (Markus *et al.*, 2002). Larger organisations implementing an OKC focussed initiative will have several types of target audiences with different backgrounds, preferences and abilities. In such cases it may prove very helpful to keep the seven principles of universal design in mind.

3.4.2.3   Knowledge Visualisation and Universal Design

Universal Design is not about just catering for the physically disabled alone. It takes a much wider angle and seeks to take into account the full "*spectrum of human ability*" (Story, *et al.,* 1998) in terms of any product or service. Universal strives to provide products that are useful and usable to as wide a section of the population as possible and not to exclude or stigmatise anybody (ibid). The designer of any knowledge visualisation effort where the target group is a disparate group of individuals must strive for the same goal.

Section 3.3.2, discussing ambiguity, has shown that this sentiment at least to some degree is already present in knowledge visualisation.

3.5 Knowledge Maps

Knowledge maps display previously captured information and its relationships (Vail, 1999). The IT section of an organisation, so Vail (1999), is perfectly positioned to take care of the creation and maintenance of knowledge maps since it cuts across all the potential silos of the modern organisation. The implementation can range from the most simple to the sophisticated. There are no prototypes or standards for knowledge maps (Pereira *et al.*, 2007). The type of implementation depends on the context in which and the purpose for which the knowledge map is used. *Figures 3.21* to *3.25* provide a few examples of different knowledge map types of increasing sophistication.

Knowledge Area	Expert	Office	Telephone
File Transfer Protocol	Hank P.	AG01	987 1234
TCP/IP	Peter T.	BF10	986 2345
EMail System	Susan E.	AF02	987 5678
Web Server	Heike W.	AF02	987 5699

Figure 3. 21: Most Simple Knowledge Map (Yellow Pages)

Knowledge Area	Expert	Office	Telephone	Source Location	Source Name
File Transfer Protocol	Hank P.	AG01	987 1234	H:\Experts\Hank	<file_name_1> <file_name_2> <file_name_n>
TCP/IP	Peter T.	BF10	986 2345	G:\Experts\Peter	<file_name_1> <file_name_2> <file_name_n>
EMail System	Susan E.	AF02	987 5678	H:\Experts\Susan	<file_name_1> <file_name_2> <file_name_n>
Web Server	Heike W.	AF02	987 5699	H:\Experts\Heike	<file_name_1> <file_name_2> <file_name_n>

Figure 3. 22: Slightly More Sophisticated Yellow Pages

Source: Eppler (2006) Figure 1: A table-based departmental knowledge assessment map of an IT consultancy
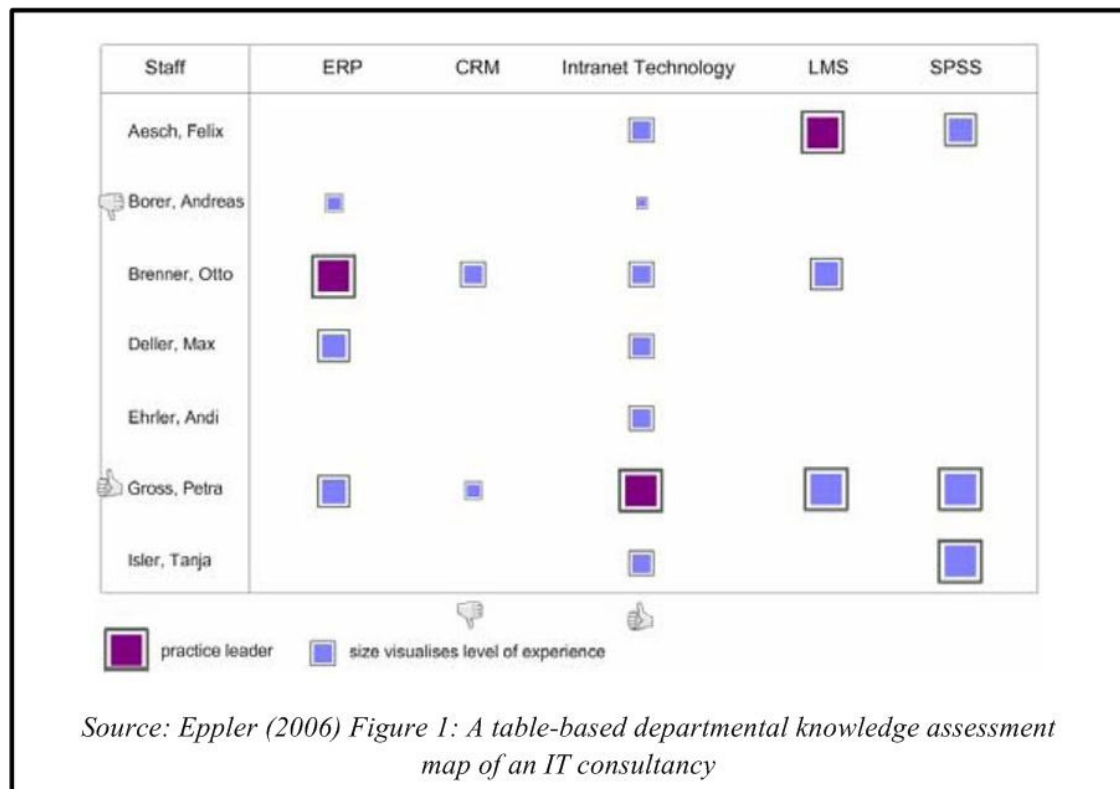
Figure 3. 23: Different Type of Table-Based Knowledge Map

In considering *Figure 3.24*, research showing that "visual images preserve metric spatial information" (Kosslyn et al., 1978) must be kept in mind. The results imply that the scanning of a small-scale image of a larger object requires the same cognitive effort, as does the original. The KM technologist needs to consider this when using the depicted approach.

Source: Eppler (2006) Figure 7: An (anonymized) metaphoric identification map of a bank
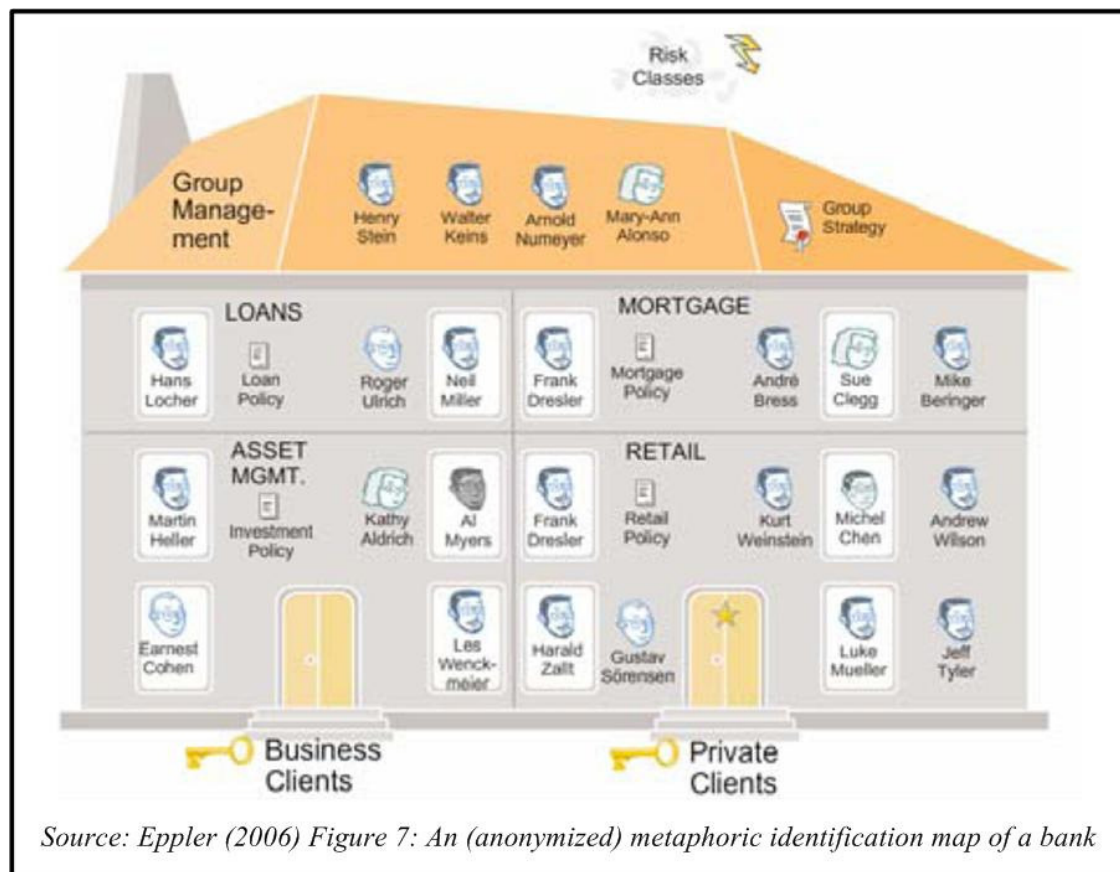
Figure 3. 24: Metaphoric Knowledge Map

Source: Eppler (2005) Figure 1: The conceptual framework for the tool development in the domain of visual knowledge communication, p. 519
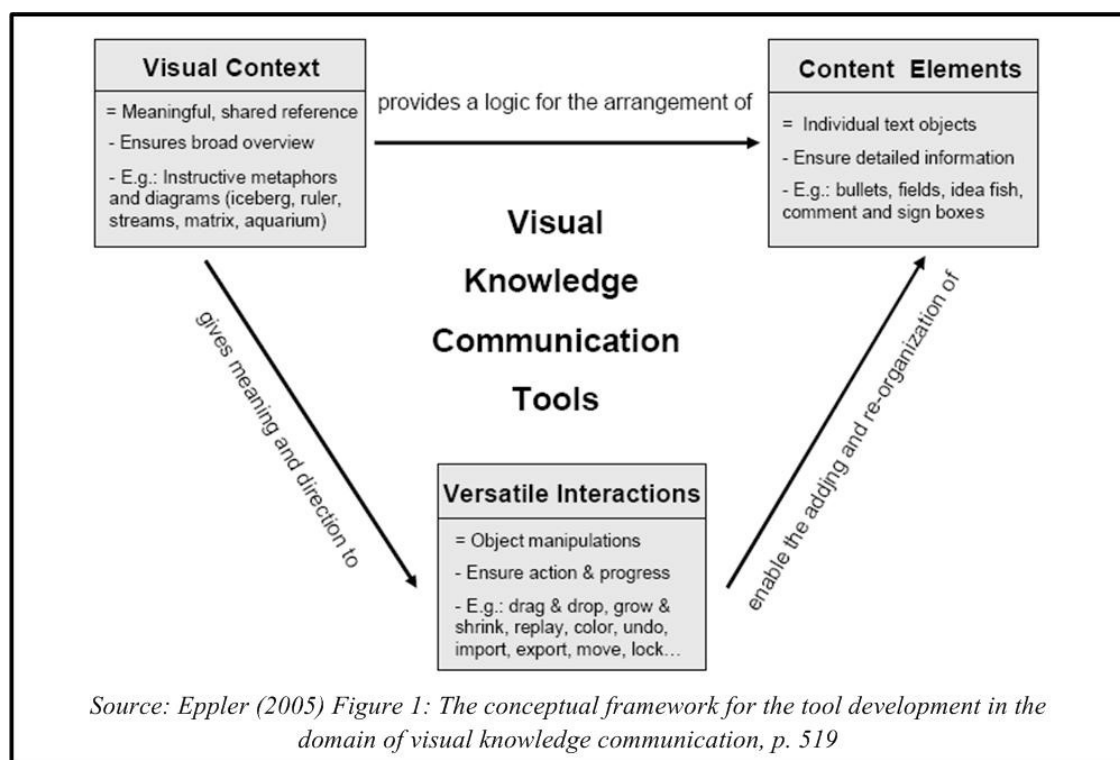
Figure 3. 25: Conceptual Diagram

Knowledge maps constitute one of the most important subsets of knowledge visualisation in terms of KM since they have a strong focus on knowledge transfer (Vail, 1999; Eppler, 2001; Burkhard *et al.*, 2005; Mengis and Eppler, 2006; Pereira *et al.*, 2007). Knowledge maps, according to Eppler (2006) have been and are still used in the following fields of study:

- *Instruction Methods (Education)*
- *Organisational Studies*
- *Requirements Engineering*
- *Information Retrieval*
- *Decision Support Systems*
- *Artificial Intelligence*
- *Knowledge Management*

Knowledge maps differ from information systems insofar as they allow for a bottom-up approach, while information systems generally are designed and implemented based on top-to-bottom data models (Vail, 1999). This fixation on data models with the latter, according to Davenport (1997, p. 6) does not address the true needs of the organisations. Knowledge maps are guides and not repositories (Davenport and Prusak, 2000, p. 72; Pereira *et al.*, 2007). Davenport (1997, p. 163) makes the point that it is far more important to give an overview on the information available at any given point in time and where the information can be found. However, a knowledge map, even of the simplest form, can be the interactive entry point to a larger knowledge system. Clarity, speed and effectiveness are indispensable for knowledge transfer in organisations; this poses several challenges (Burkhard *et al.*, 2005):

- Depth of the Knowledge
- User Limitations
- Variety of Backgrounds
- Relevance

In presenting the user with knowledge, a fine balance between detail and overview must be found. Knowledge maps address this by providing both, overview as well as detail (Burkhard *et al.*, 2005) Issues like time restraints, available attention and

cognitive capacity of the user must be taken into account. The eyes of the user need to be directed to the relevant areas (Veksler and Gray, 2007), a well-designed knowledge map can achieve this.

No single type of knowledge map will provide the solution to all domains of knowledge and purpose (Wang, 2002). Finding and designing the right map for the right task is therefore a rather crucial task in KM based on OKC. There are numerous ways to classify knowledge maps (Eppler, 2006) for that purpose (*Figure 3.26*). It would be beyond the scope of this dissertation to present any broader detail on the issue of classification.
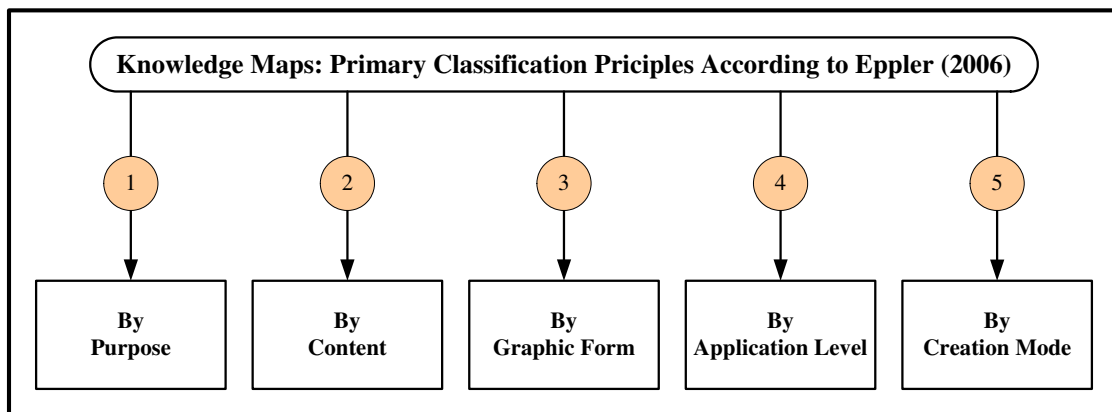
Figure 3. 26: Classifying Knowledge Maps

Knowledge maps in practice are not restricted to one of the above examples; instead there will be combinations depending on context and precise purpose (Eppler, 2001). One very important subset of knowledge maps is the field of concept maps. This subset is so significant that, many authors (e.g. Gómez *et al.*, 2000; Gordon, 2000; Wang, 2002; Trumpower and Goldsmith, 2004) in fact discuss *concept maps* when using the term *knowledge maps*.

3.5.1 Concept Maps

Concept maps were developed by Joseph D. Novak in the 1970s (Cañas *et al.*, 1996) and build to a significant degree on the psychology of learning as proposed by David P. Ausubel since the 1960s (Novak and Cañas, 2008). The concepts of *meaningful*

learning (Ausubel, 1968, p. 58) and *advance organisers* (ibid, p. 137) are of particular importance in the field of concept mapping. The term concept can be defined as

> " ... *a perceived regularity (or pattern) in events or objects, or records of events or objects ...*" (Novak and Cañas, 2008)

Meaningful learning happens when new concepts are assimilated into the framework of already existing concepts (Ausubel, 1968, pp. 58 - 62). The presentation of information demands context or structure (Naeve, 2001). This structure or context can take many forms. A dictionary for instance organises its content alphabetically; the individual entries therefore do not feature any semantic context (ibid). Concept mapping is a powerful tool to represent concepts and their interrelationships graphically (Hilbert and Renkl, 2009). Gul and Boman (2006) consider concept maps even as meta-cognitive tools since complex knowledge or information can be condensed without losing meaning and complexity. This type of knowledge map is primarily used to represent inert relationships between different concepts but can also be employed to represent dynamic relationships (Safayeni *et al.*, 2005). Concept maps recently receive increasing focus particularly for the capturing of the tacit knowledge of experts (Novak and Cañas, 2008). The structure of concept maps depends on their exact context; maps portraying similar concepts can therefore have completely different structures (Naeve, 2001; Cañas, *et al.*, 2005; Novak and Cañas, 2008). If the concepts and the linking words have been chosen with great consideration, concept maps are excellent tools to observe even finest nuances. For that reason concept maps find application in for instance education (Gul and Boman, 2006) with the purpose to determine if the student has understood complex topics (Cañas, *et al.*, 2005; Safayeni *et al.*, 2005). Research shows that the learning outcomes can be achieved more effectively and with less frustration when concept maps rather than text-based representations of hypertext interfaces are used (Kim and Olaciregui, 2008; Hilbert and Renkl, 2009). Safayeni *et al.* (2005) characterise and describe concept maps as follows

- ❑ Graphs comprising boxes that are connected by labelled arcs.
- ❑ Concepts are placed as text into the boxes.
- ❑ The relationships between the different concepts are specified on every arch.
- ❑ A unique feature of concept maps are triads of Node - Link - Node or propositions.

❑ Labels encode concepts. Labels and concepts therefore must be considered carefully since this leads to an increased variability in its meaning to the decoder. The latter may be unfamiliar with the frame of reference under which the concept was encoded thus leading to potential ambiguity and miscommunications as addressed in Sections 2.8.3 and 3.3.2.

Figure 3.27 exemplifies the basic structure of a concept map. The actual implementation depends on the sense of aesthetics of the creator.
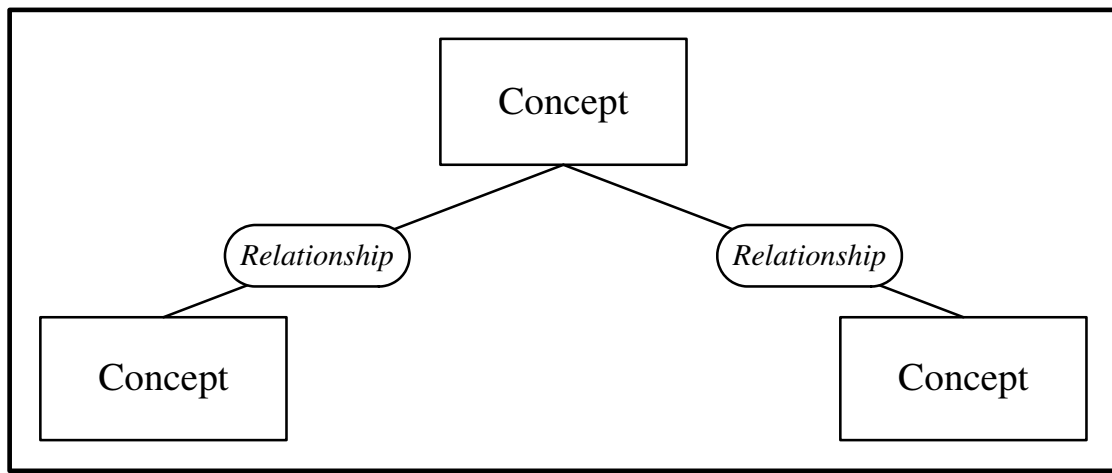
Figure 3. 27: Basic Structure of Concept Map

Figure 3.28 provides an example of a concept map explaining the bidding process of an online auction house.
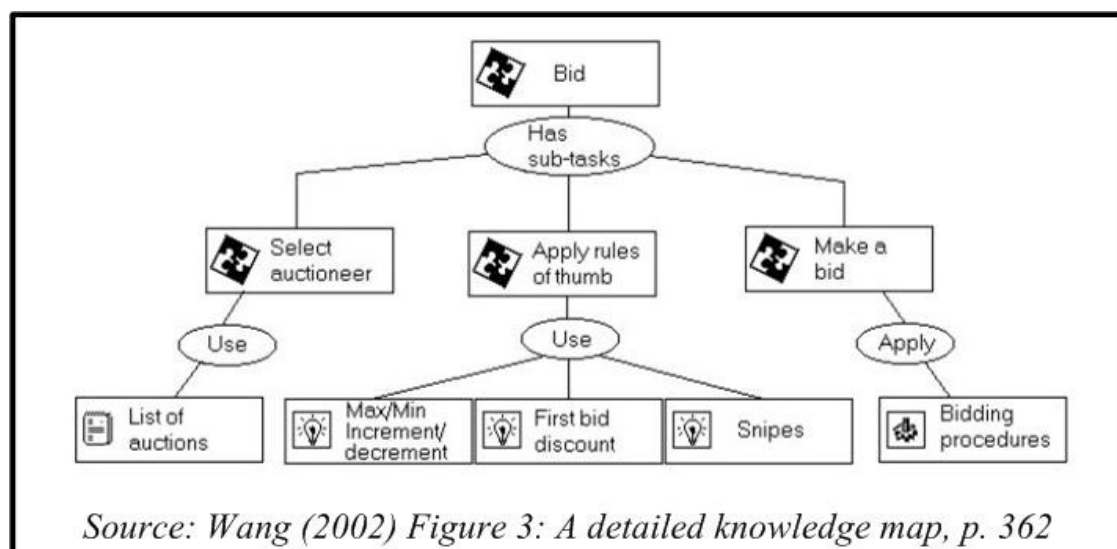
Figure 3. 28: More Detailed Concept Map

3.5.2 Knowledge Maps and Learning

Knowledge maps address the critical bottleneck of personal attention and learning capacity (Davenport and Prusak, 2000 p. xiv). They can also be seen as facilitating learning tools (Pereira *et al.*, 2007) for the individual and the organisation. The creation of a knowledge map allows the organisation to learn about itself since it identifies areas of deep, shallow or altogether missing knowledge (ibid). Gordon and Bull (2004) propose a metamodel of learning styles (Figure *3.29*) detailing different styles people prefer in their learning.

After: Gordon and Bull (2004) Figure 2 - The Gordon-Bull Metamodel of learning styles
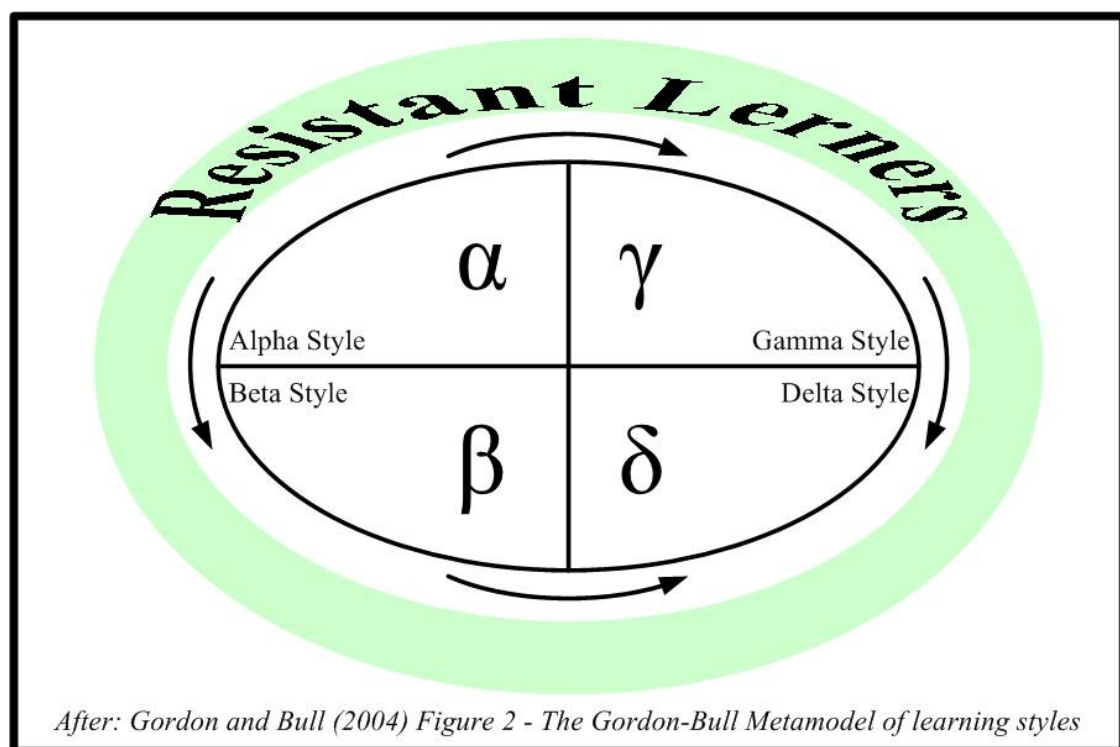
Figure 3. 29: Gordon & Bull Metamodel of Learning Styles

❑ **Alpha Style Learners:** Practical Learners who prefer clearly structured topics and like to understand the relationship between the actual world and the topic taught (ibid).

❑ **Beta Style Learners:** Discussion-oriented learners who prefer group work and get the most out of intrapersonal learning (ibid).

- **Gamma Style Learners:** Holistic learners who have a preference for an outline on the taught topic before exploring specific details. This type of learner is highly imaginative and brings this trait into the process of learning.

- **Delta Style Learners:** Very analytical and dispassionate learners who focus on logic, theories and concepts.

- **Resistant Learners:** Individuals who do not wish to join the learning experience. This reluctance may be due to various reasons like for instance a lack of self-confidence in terms of ICT use.

Knowledge maps, particularly those of the interactive kind, due to their nature support all these styles. Even the resistant learner is not excluded since the technology is not difficult to handle. Here an inherent adherence to the applicable Principles of Universal Design can be seen.

3.5.3 Knowledge Maps Supporting the Organisation

Technologies of a complex nature impose a significant burden on any adopters (Ravichandran, 2001). While the creation of knowledge maps is not an easy endeavour, it compares favourably with the implementation of large information systems in terms of time, resources and cost. Knowledge maps allow for the "understand the implications, start low - aim high" school of thought (Storey and Barnett, 2000) and therefore can be implemented with the aim for a sustainable quick win and the ever more important just-in-time imperative (Vail, 1999).

Such just-in-time and sustainable quick wins can be:

- Allowing new staff members, people who switch roles and third party staff to familiarise themselves quickly with the concepts and structures they need without diverting the attention of experienced colleagues who generally already are busy (ibid).

❑ Achieving staff buy-in to projects and changes by providing them with a knowledge map based overview on the goals, requirements and implications (ibid).

❑ The modern organisation features representatives from diverse educational, cognitive and cultural backgrounds. People in different positions and diverse lines of work require that different elements of the body of knowledge are presented to them in assorted ways, at different levels.

Vail (1999) addresses the issue of disparate views of the same environment between organisational management and IT management; The former see processes as a means to implement strategy in order to reach results through people and equipment; The latter view the same processes a requirement sources for the building, management and evolution of applications and systems.

These specialised views of the two groups are not well understood by one another. This situation, so Vail (1999) elucidates, creates a communications gap between organisational and IT management as illustrated in *Figure 3.30* below.

After: Vail(1999) Exhibit 1: The Business Process and IT Communications Gap, p. 17
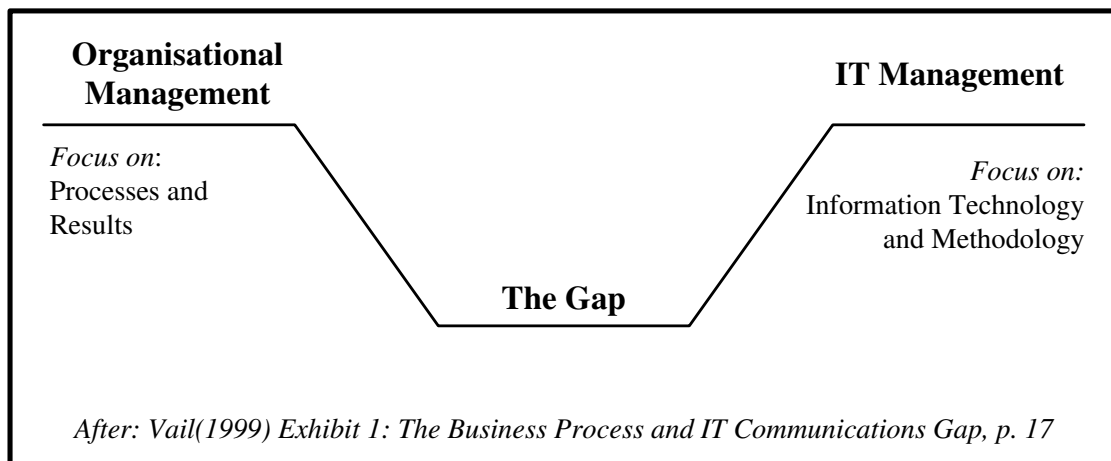
Figure 3. 30: Gap between IT and Organisation

It seems obvious that such a gap can lead to misunderstandings and miscommunications fit to not only impair but to even halt the turning of the *SPIRAL*. Vail (1999) reasons that this gap in fact has held back the effectiveness of the IT contribution for decades. Knowledge maps help bridging that gap (Vail, 1999) by

creating shared meaning and context and thus a common framework for all stakeholders (Eppler, 2001). Knowledge maps are a means to combat information and cognitive overload (Wexler, 2001) by limiting the information provided at any point to what is actually needed (Vail, 1999).

3.5.4 Knowledge Map Support for OKC and the SPIRAL

Knowledge map create shared meaning (Eppler, 2001; Burkhard and Meier, 2005), can have a strong symbolic meaning to an organisation's culture (Davenport and Prusak, 2000 p. 76), and promote the sharing of tacit knowledge (Houari and Far, 2004). Knowledge maps support the transfer of knowledge throughout the organisation and make it easier for the individual to find information (Eppler, 2001) and are useful in the elicitation, sharing, learning and creation of knowledge (Van den Berg and Popescu, 2005).

That not only is in line with OKC but also shapes the environment in favour of the information forager as described by Pirolli and Card (1999). It is helpful for the user if the design of diagrams is based on already existing knowledge structures (Larkin and Simon, 1987). This allows the transfer of cognitive skills (Pennington, *et al.*, 1995). Designers and users alike need to understand the "*appropriate computational processes*" (Larkin and Simon, 1987) if diagrams are to be useful.

This obviously requires a strong relationship between mapmakers, map user, map innovators and map champions (Wexler, 2001). Such a relationship, of course, feeds the *SPIRAL*. Creating a knowledge map is a rather dynamic process. In that it satisfies the criteria for the successful transfer of knowledge as illustrated in *Figure 3.30*.

After: Liyanage et al. (2008) Figure 1, "A Process Model For Knowledge Transfer"
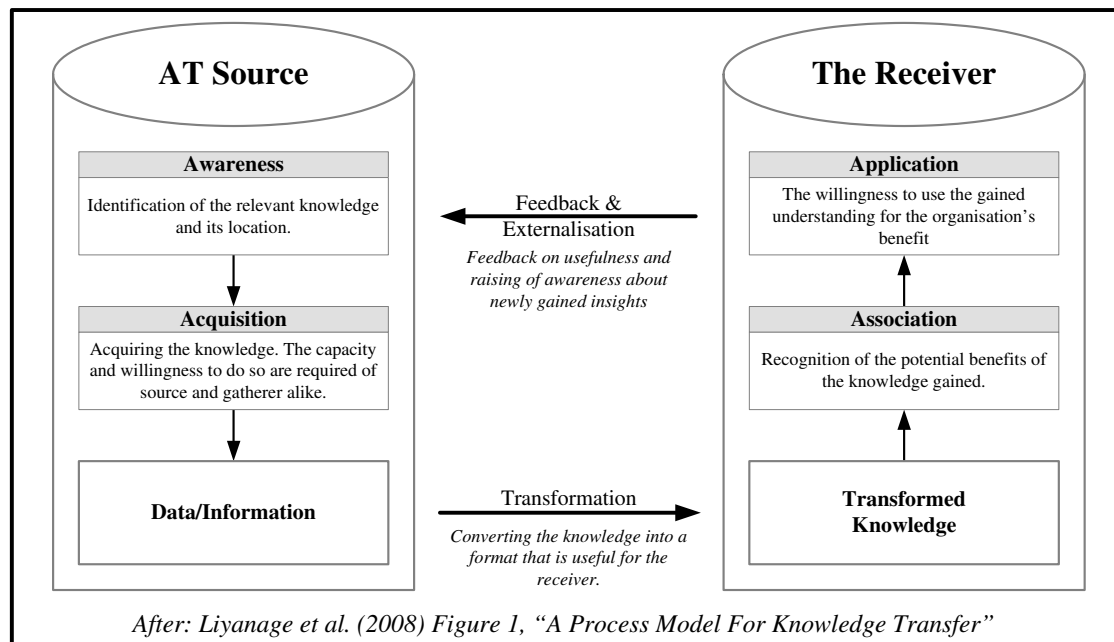
Figure 3. 31: Successful Knowledge Transfer

Knowledge maps, Wexler (2001) explains, are problem centred and need to be amended based on the experiences gained by using and reusing. In their initial creation, much data and information needs to be gathered and analysed (Pereira *et al.*, 2007). Creation and transfer of explicit and tacit knowledge take place even during the sense making process of the gatherer (Cañas *et al.*, 1995; Gómez *et al.*, 2000; Eppler, 2001). It must be realised that, a concept map is never finished it needs to be revised constantly (Novak and Cañas, 2008).

Once made available, the user creates new insights through the interaction with the content of the map (Eppler and Burkhard, 2007). Those insights if included in the feedback do their part in keeping the *SPIRAL* turning. Pereira *et al.* (2007) consider the construction of knowledge maps as a fusion of explicit and tacit knowledge. This fusion supports the *SPIRAL* and thus satisfies the requirement of constant interaction between tacit and explicit knowledge as per OKC.

3.5.4.1   Supporting Socialisation

Knowledge maps, as shown in the case study of section 3.4.2.1, have the potential to get people talking to one another. The knowledge contained in the maps will therefore discussed and as a result expanded. This may occur online as well as off-line.

3.5.4.2   Supporting Externalisation

Visual mapping tools can be used even for asynchronous communications between experts and non-experts (Eppler, 2005). Two excellent examples of such tools are CmapTools (http://cmap.ihmc.us) and Conzilla (http://www.conzilla.org). Tools like these support asynchronous collective knowledge creation. Experts can pass on their tacit knowledge to non-experts through this process.

3.5.4.3   Supporting Combination

At the point of creation knowledge maps absorb knowledge (Pereira *et al.*, 2007) and at the point of usage, they allow for the re-construction (Burkhard and Meier, 2005; Eppler and Burkhard, 2007) of the contained knowledge. The knowledge contained in the map being or pointed to by the map comes from different sources. The user working with a single knowledge map will engage in combination without having to perform extra tasks.

3.5.4.4   Supporting Internalisation

During that re-construction process and through the using of the map, the viewer can be considered to engage in learning by doing.

3.6   Conclusions

Chapter two asked questions about the role of computing in OKC-based KM and concluded that, KM technologists needed to concentrate on the transfer of knowledge. This chapter introduced the field of Visualisation as the one to contain a very feasible solution. With the support of a suitable case study it was found that, knowledge visualisation through knowledge maps is indeed suited to help individuals driving the *SPIRAL* as envisioned by Nonaka (1994). Further research presented elaborated on the 'how' and 'why' of this suitability. Chapter four will present the design considerations for an experiment that was devised to test if, in terms of retention on part of the user, a graphic interface will lead to better results than a tabular interface.

4 EXPERIMENT DESIGN CONSIDERATIONS

4.1 Introduction

Chapter two raised the question of the role of computing for OKC-based KM in terms of the *WHERE*. Chapter three addressed the *WHAT*, *WHY*, and *HOW* of the same question. This chapter elaborates on the design considerations of an experiment that seeks to investigate the findings of these previous chapters. The elucidations begin with the general goal of the experiment and the reasoning behind the chosen type of experiment. This is followed by the presentation of the requirements of the experiment itself and the tool that is to function as the container. The chapter continues with an exploration of design decisions made and the evolutionary development of certain aspects of the design. Deliberations on the approach to the distribution of the experiment complete this chapter.

4.2 Design Goals and Requirements

Alavi and Leidner (1999), as previously addressed in Section 2.6.2, found that more research with regards to design, use and success of tools that support KM (Alavi and Leidner, 2001) is needed. While considerable research has been conducted since this statement was made, there appears to be significant room for more research in this particular area. This dissertation endeavours to produce a small contribution to the existing body of research.

Much of the relevant research deals with images and perception in isolation. The experiment explained in this chapter simulates a small knowledge base that is fronted by two different interfaces where both have been inspired by knowledge maps. This is to test the findings of chapter three in a context as could be encountered in real life.

4.2.1 Design Goals

The experiment seeks to implement some of the lessons drawn from chapter three for one of the two interfaces. The issues this experiment is designed to investigate are as follows:

❑ Do a different knowledge base interface lead to a difference in the recall ability of the participants?

❑ Will the individual users recognise the interactivity of components and use them?

❑ Are there any known or unknown variables that must be taken into account when embarking on such an endeavour?

❑ What are the potential issues that might arise in cases where a similar knowledge map front end is being implemented?

The experiment will test the recall of participants by presenting a few predetermined test questions and recording the answers. The activities performed by the users must be tracked and recorded in order to make it possible to determine whether or not the provided features have been recognised by the user as such. Any problems arising during the distribution or the actual conducting of the experiment may point to issues KM technologists might want to be aware of before implementing any similar tool.

4.2.2 Experiment Requirements

The experiment will divide the participants into two independent groups. Each group will be presented with identical information on four areas of expertise using either one of two possible knowledge-map-inspired interfaces. The information provided consists of some personal information on the experts associated with their area of expertise and some links to documents the user must be able to call up. The experiment content must be engaging. Topic and nature of presentation must encourage the participant to call up all information provided. One interface is to be of a tabular nature, similar to the type

of spreadsheet-based "*Yellow Pages*" commonly found in organisations. The other is to be of a more graphic nature, featuring two layers. The first layer is to represent the four sections containing only the information on the experts for each of the area of expertise. The second layer is to contain the links to the aforementioned documents in the form of a simple concept map. The experiment is to be divided into six individual stages where each single stage is clearly recognisable by the participant. On progressing from one stage to another, the user must be made aware that s/he has completed one stage and is about to enter the next.

Figure 4.1 provides a comparison view of the two front-ends to the same knowledge base. The graphic version, as can be seen features two layers whereas the tabular version only features one layer.
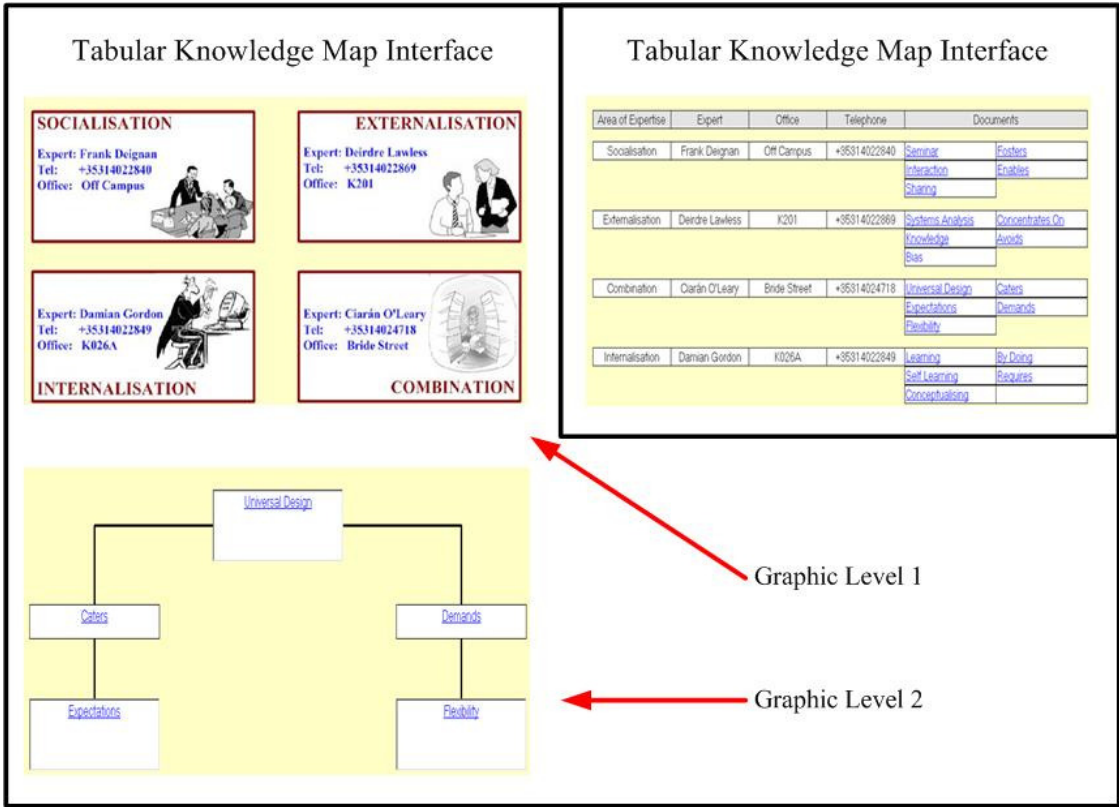
Figure 4. 1: The Two Knowledge Map Interfaces

4.2.1.1   The Six Stages of the Experiment

❑ *Stage 1 (Introduction/Welcome)*

  ▪ This stage is to give the participant an overview of what s/he can expect to happen during the process.

❑ *Stage 2 (Statistical Questions)*

  ▪ Generalised, personal questions need to be asked for the statistical analysis of the gathered data.

❑ *Stage 3 (Exploration of the Information or Search Space)*

  ▪ The participant is given the opportunity to browse the entire content without any time limit.

❑ *Stage 4 (Performing a Task)*

  ▪ The participant is to find a specific piece of information from within the search space. This piece of information must not be hidden or difficult to find. It therefore will be a single word within a sentence that stands out from its context. The participant who has examined the structure of the information provided should be enabled to some determine the field of expertise in which the answer can be found.

❑ *Stage 5 (Recall Test)*

  ▪ The participant will be asked a few questions, no more than ten, with the aim to test if the interface was supporting his/her recall.

- *Stage 6 (Closure/Final Instructions)*

  - The participant will be thanked for participation and informed that the process has completed. Instructions need to be given on how to deliver the data set that is to be generated automatically.

4.2.3 Tool Requirements

The experiment will require a tool to serve as container for the successful delivery of the experiment. That tool must meet the following requirements.

- Display all information and instructions needed for successful delivery.

- Determine the nature of the interface (tabular of graphic) at run-time

- Cater for a step-by-step progression.

- Capture user responses to statistical questions.

- Track the participant's action during the exploration and task stages.

  - Capture events where users hover over any relevant component or click on a relevant component.

  - Take a time stamp of commencement and the completion of the event and calculate the duration of the event.

- Capture the user's responses to the test questions.

- All captured information must be written to a simple text file.

  - That text file needs to be formatted in a way that makes it easy import the individual data sets into a desktop database application.

  - The format must make it possible for the content to be legible from within the file itself. It must support the quick visual scanning by any viewer.

Figure 4.2 gives a graphic overview on the different experiment stages and indicates specific actions and activities the tool must perform.
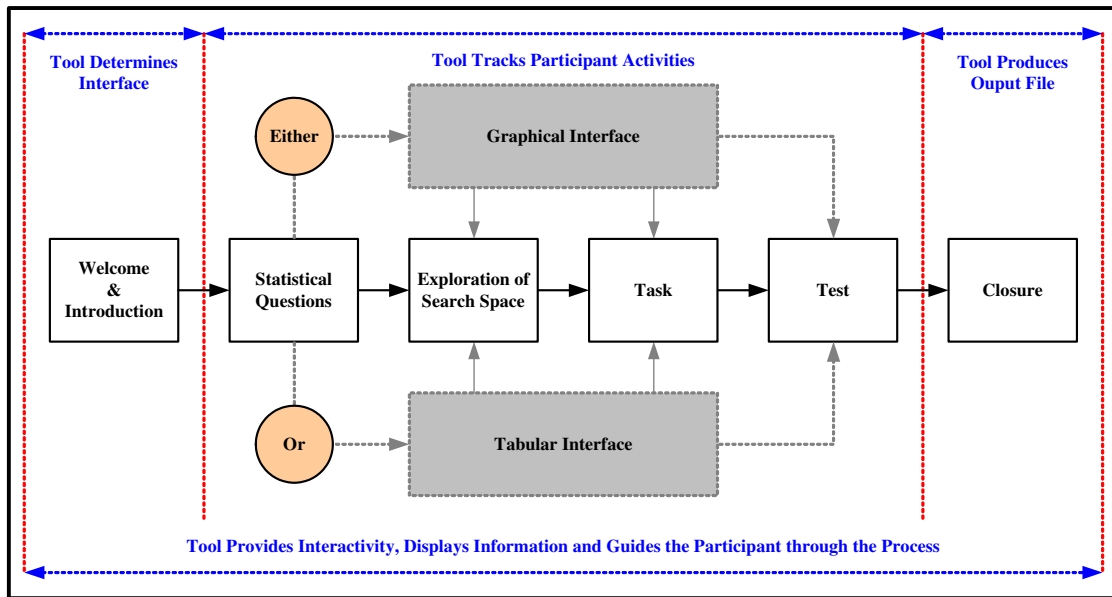
Figure 4. 2: Experiment Overview

4.3 Design Decisions

This section introduces and discusses the decisions that have shaped and determined the nature, look and feel of the life experiment.

4.3.1 Design of the Experiment

4.3.1.1 The Knowledge Base

The content of the knowledge base is to be stored in individual text files. The same applies to all information specifying their location. In order to allow the easy access form both interfaces, the files are to be organised in the fashion as listed in *Table 4.1*.

Area of Expertise	Area 1	Area 2	Area 3	Area 4
Expert	Expert 1	Expert 2	Expert 3	Expert 4
Office	Location 1	Location 2	Location 3	Location 4
Tel	Tel 1	Tel 2	Tel 3	Tel 4
Master Concept	**File 0**	**File 5**	**File 10**	**File 15**
Relationship	File 1	File 6	File 11	File 16
Concept	**File 2**	**File 7**	**File 12**	**File 17**
Relationship	File 3	File 8	File 13	File 18
Concept	**File 4**	**File 9**	**File 14**	**File 19**

Table 4. 1: Experiment Knowledge Base

4.3.1.2 Welcome/Introduction

The introduction is to be of the utmost simplicity. It may be spread over several screens. The sentences are to be kept short and clear. Information on the following issues must be provided on the purpose of the experiment, the number of stages, and an estimated time for completion. Sweller (1988) points out that the information

forager will not read any lengthy document. This was confirmed by the prototype trial run where exhaustive explanations were ignored.

4.3.1.3   Statistical Questions

Participants were asked 10 questions for statistical evaluation. Each question was chosen for a particular reason. This section explains their rationale.

Which age group do you belong to?	Are you male of female?
Do you wear corrective lenses (glasses, contacts)?	Are you left-handed?
What is the main activity of your life about?	What is your first language?
Do you use English on a daily basis?	To what extent do you work with computers?
In learning, what works best for you?	Are you familiar with **SUBJECT AREA**

Table 4. 2: The 10 Statistical Questions

In addition to the reasons stated below, questions 1 to 8 in particular serve to detect any potential *Sample Bias* (Coolicon, 2004, p. 35). It might arise since, the approach to experiment distribution and delivery, as addressed in Section 4.5, relinquishes any control over the *sampling frame* or *target population* (ibid).

Question 1 (Which age group do you belong to?)

Research provides strong indications that age has an impact on visual perception (Mendelson and Wells, 2002; Lindberg *et al.*, 2006; Voss *et al.*, 2008; Roudaia *et al.*, 2008) regardless if an individual is visually impaired or not. This question therefore needs to be asked since the experiment deals with visual perception. To be as inclusive as possible the following options are provided.

17 - 20	21 - 30
31 - 40	41 - 50
51 - 60	61 - 70
71 - 80	81 - 90
91 - 100	101 and above

Table 4. 3: Question 1 - Options

Individuals below the age of 17 are not expected to participate since this research effort is about individuals in organisations and not about primary or secondary level school education.

Question 2 (Are you male of female?)

Eppler and Platts (2007) find significant differences between men and women in their classification of visual images. This question is designed to test if this may have an impact on the individual performance.

Question 3 (Do you wear corrective lenses (glasses, contacts)?)

This is a Yes/No question. The wearing of corrective lenses can have an impact on an individual's perception (Bertone *et al.*, 2007). This piece of information may prove vital in the interpretation of specific result sets.

Question 4 (Are you left-handed?)

This is a Yes/No question. Research suggests that there are significant differences between left-handed and right-handed individuals (Chen and He, 2003). This applies to, but not exclusively, areas like colour detection (Sasaki *et al.*, 2007) and the processing of information on spatial frequency in terms of contrast levels (Okubo, M. and Nicholls, 2005).

Question 5 (What is the main activity of your life about?)

This question is inspired by the principles of *Universal Design* (Story, *et al.,* 1998) as briefly addressed in Section 3.4.2.3. Asking for an occupation or a job title would stigmatise all those that are neither self-employed nor in salaried employment at the time of participation. The participant is offered the following options.

Handling Technology (Computing)	Handling Technology (Other)
Dealing with Data or Numbers	Dealing with People
Leading/Motivating People	Teaching People
Studying: Humanities	Studying: Arts
Studying: Business	Studying: Computing
Studying: Engineering	Other, please type it in here

Table 4. 4: Question 5 - Options

Research conducted by Eppler and Platts (2007) indicates that people in different roles approach the interpretation of images from different angles. They conclude that for future research it would be beneficial to differentiate particularly between students of different disciplines. This accounts for the many options on studying.

Question 6 (What is your first language?)

Sections 2.8.3 and 3.5.3 raise the issues of the increased mobility and the diversity of the modern organisation's work force. It can no longer be assumed that individuals with Irish, UK, German, etc. nationality or residence are native Gaelic, English or German speakers. Asking for either nationality of country of residence would be futile. The participant will be provided with the list of all languages that are listed as official languages of the European Union (European Commission, 2009). In addition to that, the participant will have the option to type in a language if the list proves insufficient.

Question 7 (Do you use English on a daily basis?)

This question is designed to help determine whether or not it is possible that a language barrier may have influenced the results. Asking participants for their self-assessed proficiency in the English language might lead to unreliable results and would clearly breach the first principle of Universal Design (Story, *et al.,* 1998). The combination of the answers to questions six and seven, will allow a reasonably accurate interpretation of the individual's proficiency in the English language. The participant is given the following options:

Exclusively	Mostly
At work only	In social interactions mostly
Rarely	Practically never

Table 4. 5: Question 7 - Options

<u>*Question 8 (To what extent do you work with computers?)*</u>

This question is designed to determine whether or not it is possible that the computer skill of an individual participant may have influenced the outcome. The fact that an individual takes part in the experiment means that, s/he is using a computer (as in PC or equivalent) at least on occasion. An option like 'Practically Never' is therefore not considered.

Constantly at work and at home	At work constantly
At work occasionally	At home constantly
At home occasionally	

Table 4. 6: Question 8 - Options

<u>*Question 9 (In learning, what works best for you?)*</u>

The experiment aims to collect self-report and objective usage data as called for by Money and Turner (2004). This particular question is designed to collect the subjective self-assessment given by participants in order to compare it to the actual data set produced by that user. It may be useful in the assessment of outlier data sets. The options provided are as follows.

❑ Visual Material
❑ Text-Based Material
❑ A Combination of Both

<u>*Question 10 (Are you familiar with the making of Sauerkraut?)*</u>

Sections 2.8.3 and 3.4.2.2 briefly touched on *Cognitive Load Theory* as proposed by Sweller (1988). Participants who already have a certain familiarity with the subject

area should be likely to have more cognitive capacity left to process peripheral information provided.

4.3.1.4   Search Space Exploration

The participant must be allowed to browse the content at his/her own pace. The tool tracks all the activities and takes note of, which objects the participant explores by hovering over with the mouse cursor and which objects are being clicked on. The duration of any such event is to be recorded in milliseconds. The data gathered should provide sufficient information the draw a picture of the participant's sincerity. It is at this stage that the two groups for the first time are presented with differing interfaces. The graphic group will have the advantage that the total amount of chunks of information is reduced through the two-layer design.

4.3.1.5   The Task

Participant will be asked to find a single word that is contained within a sentence from the knowledge base. It is expected that both groups perform in and around the same level. The tabular group could outperform the graphic group since all information is accessible from one single screen. The table layout and the information contained must within itself convey some semantic meaning. Otherwise the graphic group would have a significant advantage that in turn would introduce a bias fit to invalidate the whole experiment.

4.3.1.6 The Recall Test

Each Participant is to be asked 10 questions about information contained in the interface and the knowledge base.

#	Question	#	Question
1	Ask for expert name	2	Ask for expert name
3	Ask for expert name	4	Ask for expert name
5	Ask for office location	6	Ask for relationship
7	Ask for relationship	8	Ask for relationship
9	Ask for Relationship	10	How many areas of expertise were there?

Table 4. 7: The Recall Test Questions

It is expected that questions one through to five will produce a difference in outcome. Reason being is that, the graphic group receives visual cues that are not available to the group presented with the tabular interface. Questions 7, 8 and 9 are about some relationships as indicated by the knowledge base. The outcome is expected to depend on the individual depth of the exploration of the knowledge base. For the sake of accuracy in the evaluation, the user is provided with the prepared answer options as listed in *Table 4.8*. The options are designed to allow the user expressing negative emotions.

I do not understand the answer	I don't care
I don't know	I'm not sure

Table 4. 8: Prepared Answer Options

4.3.1.7 Closure

The participant is thanked for his/her participation and provided with simple instructions on how to locate the output file and how to submit it. Submission will be requested by email and file attachment. The name of the output file and the target email address must be made available for a simple copy and paste operation. The participant is made aware that s/he is invited to make any comments on any aspect of the experiment in the body of the email. A short statement is included reassuring the

participant that no personal details of the participant will be made available to any third party.

4.3.2 Design of the Tool

Since the tool is but the delivery container for the experiment, a detailed description of the design considerations of all individual elements is omitted. These considerations are of a technical and implementation nature and therefore will be dealt with in chapter five. This section concentrates on the vital element, the knowledge/information search space.

One of the considerations applied to all aspects and components is the need of drawing the eyes of the user to the relevant areas (Veksler and Gray, 2007) as addressed is section 3.5.

4.3.2.1 Knowledge/Information Search Space

The design seeks to at least some degree apply the principles of Universal Design particularly to the information/knowledge search space of both interfaces. The behaviour of all interactive components is modelled, as far as possible, on the behaviour of similar components on internet web pages. This is in observance of the requirement to be consistent with the user's expectations and intuition. The approach in addition to that is expected to allow the user to transfer existing skills through already familiar functionalities (Masterton and Watt, 2000).

4.3.2.1.1 Graphic Type Knowledge Map Interface

The use of metaphor in the graphic knowledge map is to be omitted. The associative chain of the designer, as addressed in Section 3.3.2, may be very different from that of the user (Rogers and Osborne, 1987). Ambiguity, as addressed in section 3.3, while potentially useful in synchronous interactions and communications like meetings and seminars, is undesirable in the effort of knowledge transfer (Eppler *et al.*, 2008). The potential of any of the seven types of visual ambiguity occurring (ibid), as also

discussed in Section 3.3.2, is too significant to take the risk. Section 3.5 reports on the research of Kosslyn *et al*. (1978) who found that the scanning of a small-scale image of a larger object requires the same cognitive effort, as does the original. The graphic version therefore does not feature images of any large objects like for instance buildings.

Figure 4.3 sketches the earliest design of the upper level of the graphic interface. While the basic concept has never changed, the actual implementation went through several iterations. Attention may be paid to the desired behaviour on any mouse-over event on any of the four quadrants.

❑ The quadrant is to change colour.
❑ The image within the active quadrant is to grow slightly but noticeably.
❑ The cursor is to change from the standard arrow to the 'click-hand' as used on internet web pages.
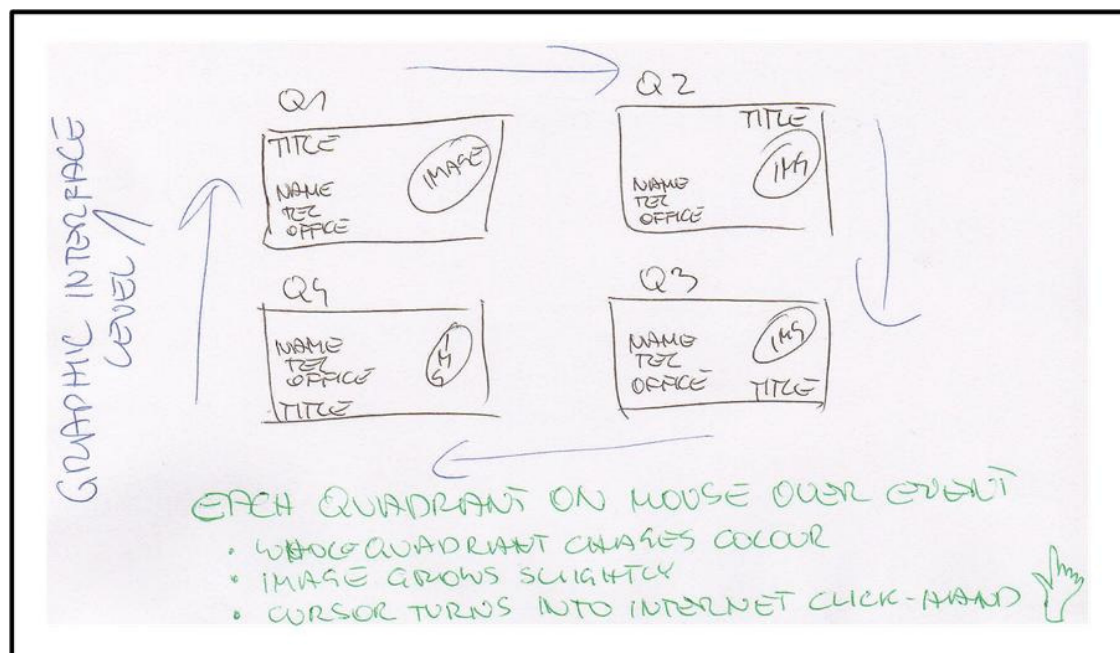
Figure 4. 3: Early Design Sketch - Graphic Knowledge Map (Level 1)

Figure 4.4 demonstrates a very early test implementation of the sketch in Figure 4.3. The four quadrants are inactive; the mouse cursor is not hovering over any quadrant. *Figure 4.5* illustrates a basic idea as to how the quadrants might look if activated by the user by hovering over them with the mouse cursor. In the actual implementation,

the images are to be chosen to help the participant's recall by supplying visual images that are associated with the area of expertise or the expert him/herself. This implements *Dual Coding Theory* (Paivio, 2006) as addressed in Section 3.2.2.

Figure 4. 4: Early Test (Graphic Knowledge Map, L1) Quadrants Not Activated

Figure 4. 5: Early Test (Graphic Knowledge Map, L1) Quadrants Activated

Figure 4.6 sketches the earliest design of the lower level (Level 2) of the graphic interface.
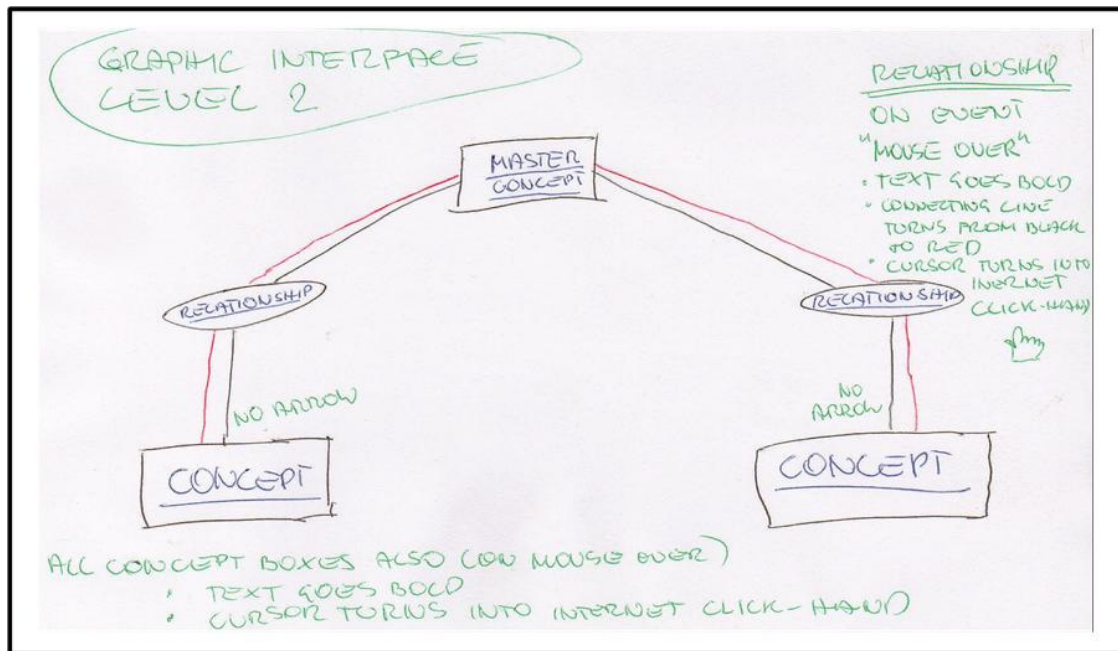
Figure 4. 6: Early Design Sketch - Graphic Knowledge Map (Level 2)

It can be seen that the behaviour of the objects on the screen do follow the internet convention of indicating its interactivity through blue and underlined text and having the shape of the cursor change on hovering over the object. The relevant connecting lines from master concept to relationship to underlying concept turn red when the mouse cursor hovers over any of the relationship objects. Arrows have been omitted since different cultures read them differently (Eppler and Platts, 2007).

4.3.2.1.2 Tabular Type Knowledge Map (Yellow Pages) Interface

Figure 4.7 sketches the layout of the tabular knowledge map interface. The behaviour of the links should indicate interactivity to the user. Attention may be paid to the arrangement of the links to the knowledge base documents on the right-hand side. This arrangement already carries some semantic meaning.
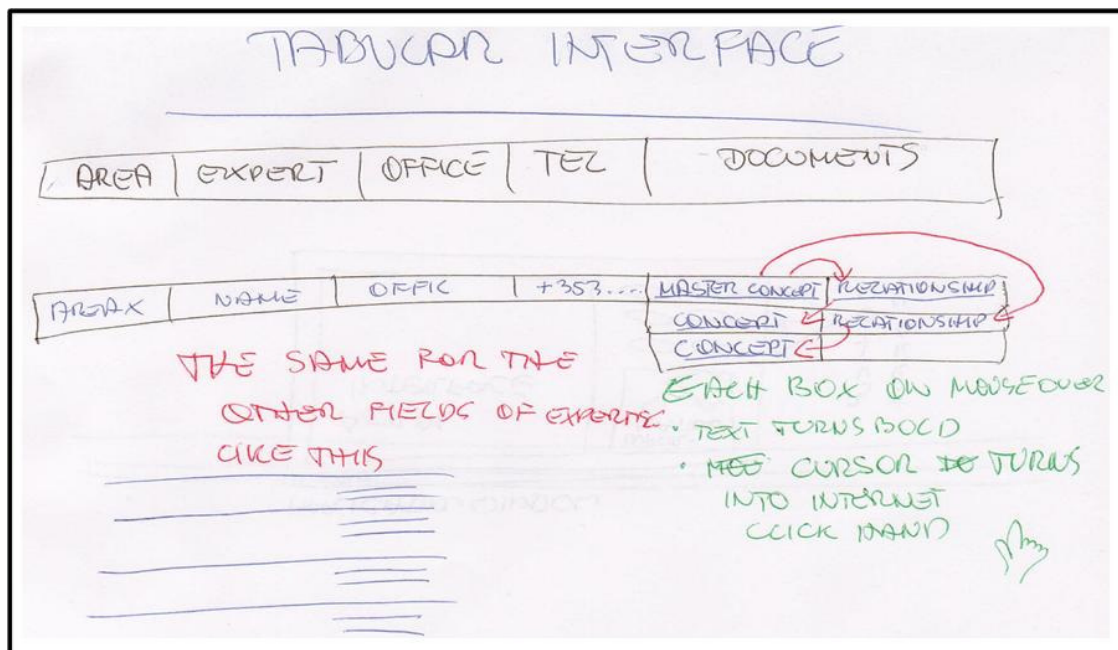
Figure 4. 7: Design Sketch - Tabular Interface

The content of any area of expertise is to appear as shown in *Table 4.9.*

Master Concept	**relates to**
Concept 1	**and relates to**
Concept 2	

Table 4. 9: Example (Reading Tabular Knowledge Entry)

This can be read, "*The master concept relates to concept 1 and relates to concept 2.* "
With that, the viewer already has an overview on the content of the information, which
the links are pointing to. Participants presented with the tabular interface are therefore
not unduly disadvantaged.

4.3.2.2   Tool Main Window Design Evolution

This section provides an overview on the evolution of the main tool window. It
identifies those components the participant requires to handle the tool itself. It is not
concerned with the actual experiment itself. The components addressed '*ACTUAL
INTERFACE*' is the container for all experiment related activity.

Figure 4.8 sketches the earliest design. This outline only serves to identify individual components. The actual functionalities of the buttons are not yet determined. The number of buttons is chosen arbitrarily. Even a swift visual scan identifies that the design resembles a television set in the style of the 1969s or 1970s. The information bar cannot perform the required function since it is too narrow for any information to be displayed in a meaningful way.
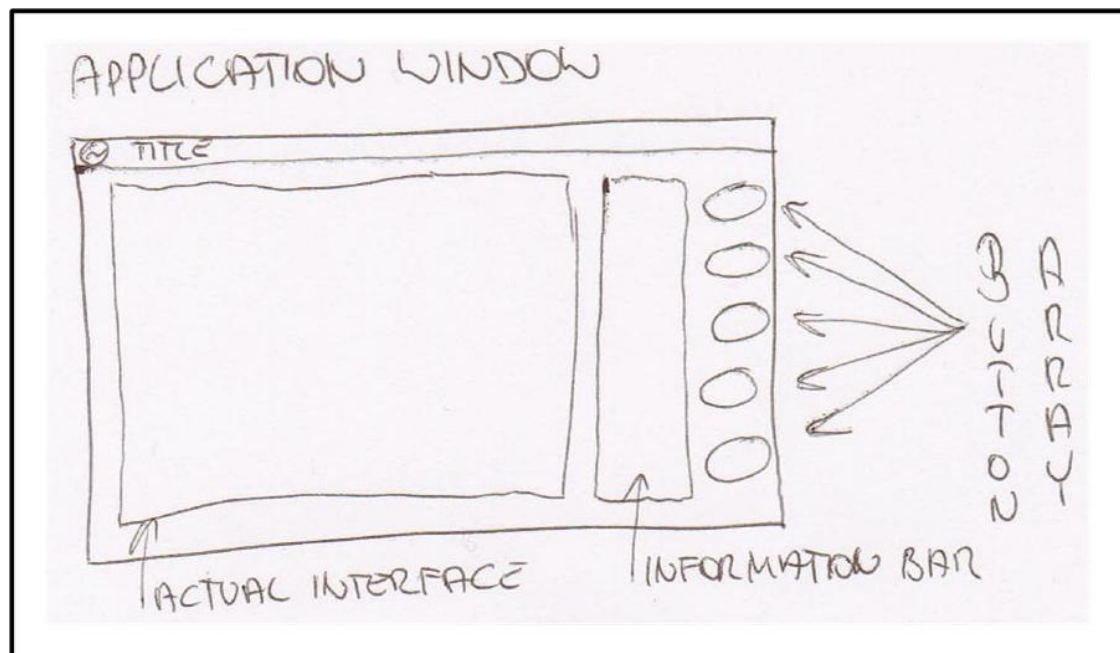
Figure 4. 8: Earliest Design Sketch

Figure 4.9 sketches still an early but more advanced design where the overall usability and placement are being taken into account. The information bar has been replaced by an information window. However, its size relation to the rest of the screen is still too small to be of any real use. The buttons still have no functionality assigned to them.
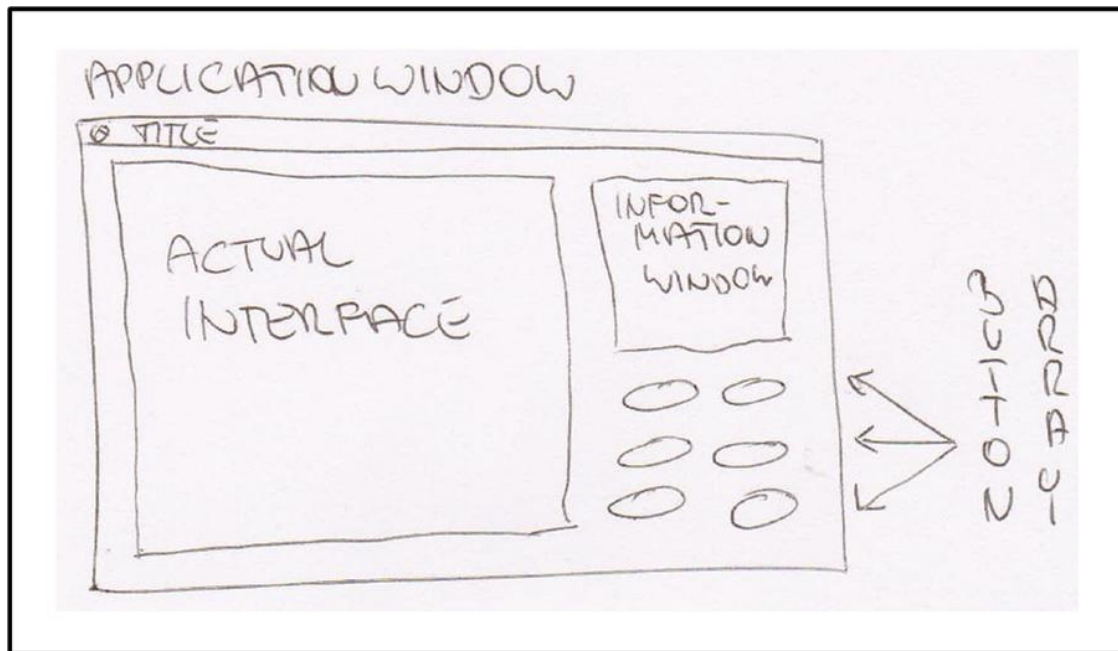
Figure 4. 9: Second Stage Design Sketch

Figure 4.10 sketches a further step ahead in the design. This draft sees the introduction of a new component, a bar indicating to the participant how far into the experiment s/he has progressed. The number of buttons is reduced to three. The overall number of components thus is reduced to six and therefore in line with Miller's (1956) stipulation of *Seven plus/minus Two* (as addressed in Section 3.2.2).
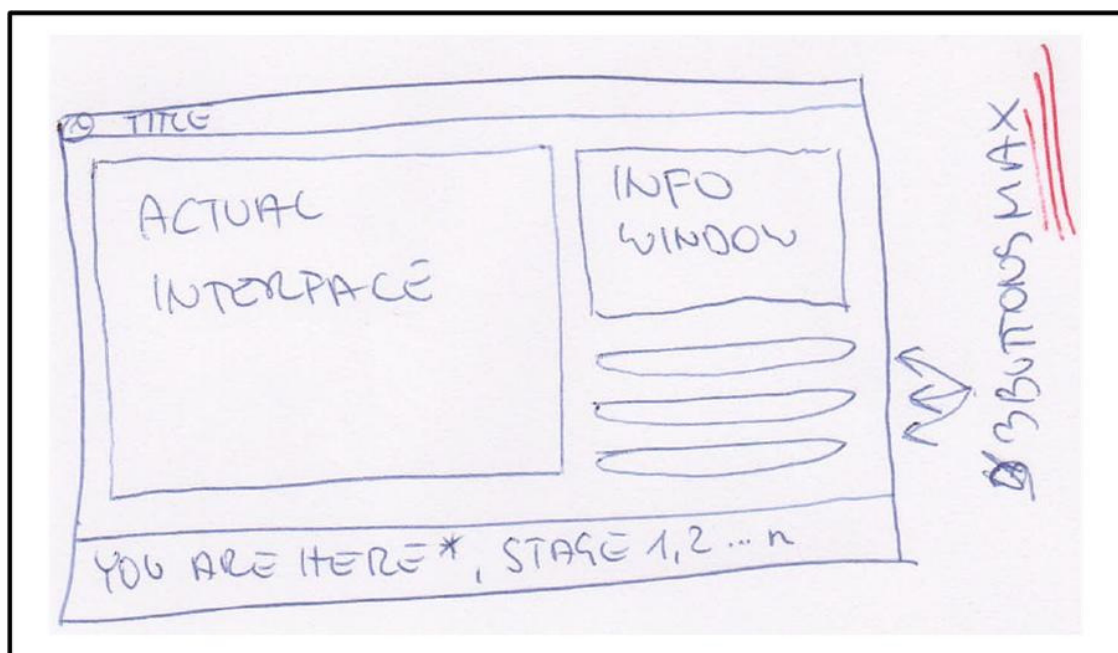
Figure 4. 10: Third Stage Design Sketch

Figure 4.11 sketches the design as implemented with the actual prototype. Location and size of the information window are now sufficiently fit for the intended purpose. The number of buttons remains at three. Each button has a functionality assigned.

The buttons 'Abort' and 'Info On/Off' are inspired by the concept of the information ecology (Nardi and O'Day, 1999, p. 27), the user should be able to develop a feeling of control over the tool (Section 2.8.2); and the principles of Universal Design (Story, *et al.,* 1998) in that they provide a certain flexibility and cater for individual preferences in the use of the tool.

❑ The button '*Abort*' is designed to allow the user a meaningful option to abort the experiment, while still being able to submit the results up to the point of aborting and being given the opportunity to explain his/her reasons for doing so.

❑ The button 'Info On/Off' is designed to turn on and off the feature of the tool, where it gives hints and advise on the feature the mouse cursor hovers over at any given time.
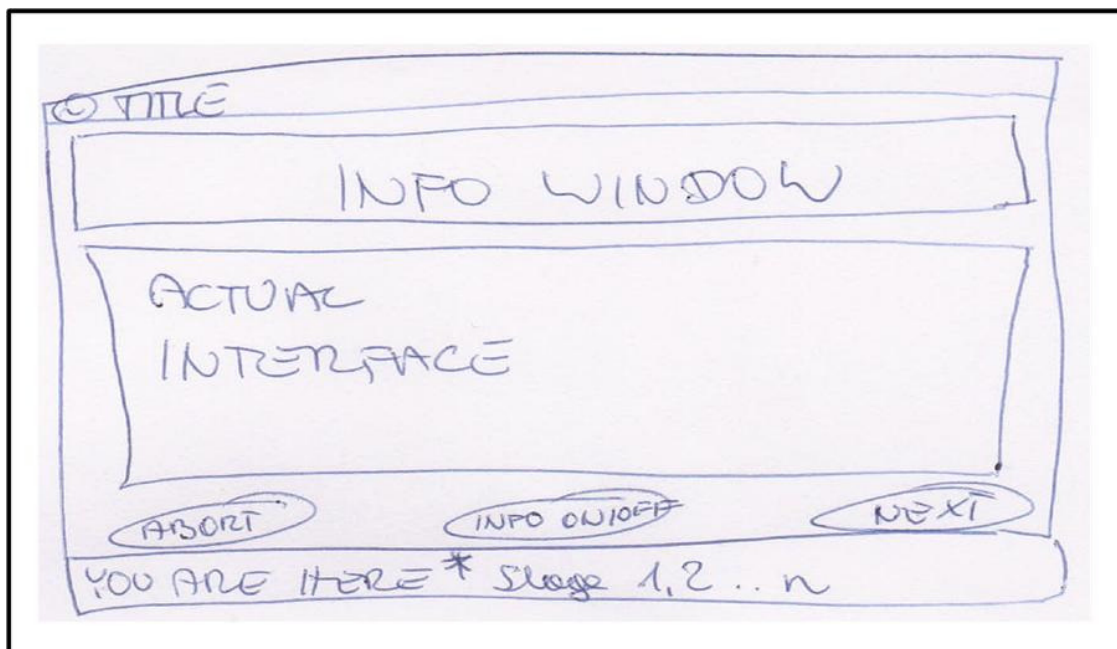
Figure 4. 11: Final Design Sketch

4.4 Experiment Distribution

This experiment endeavours to reflect the real world as closely as possible. It therefore is required to sample a most diverse group of individuals. For that purpose a network of contacts has been set up. The network consists of people who have agreed in advance to participate in the experiment themselves and to pass on the request for participation to colleagues and friends. The approach is illustrated in *Figure 4.12* below.

X: Experimenter; K: Participant known to X; U: Participant Unknown to X
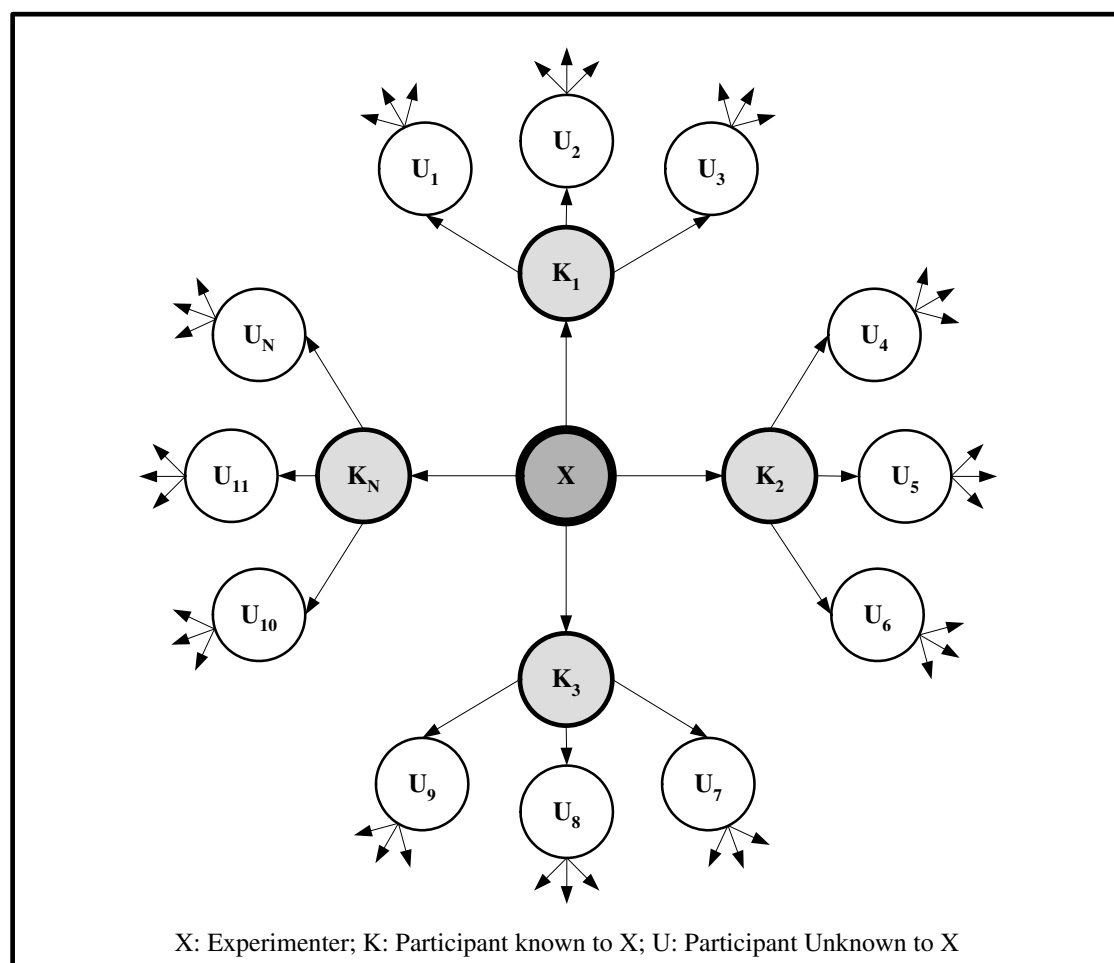
Figure 4. 12: Approach to Experiment Distribution

As a backup, several other individuals will be notified as well on the commencement of the experiment. This group will participate but not pass on the request for participation. A large number of computer science lecturers in Ireland will be contacted as a further backup measure. The actual distribution vehicle is dependent on the nature of the tool itself.

4.5 Conclusions

This chapter elaborated on the design considerations regarding the experiment itself and its container. In order to test on some of the postulations arrived at in chapters two and three two groups will be presented with identical information through two different interfaces. The experiment goals were stated as the endeavour to find if the graphic interface would lead to better recall in the participants and if either design was sufficient to support the individual participant to recognise the functionality of interface specific interface components. The experiment requirements where shown to drive all design decisions made. Chapter five will report on issues related to the implementation of the tool and its distribution.

5   EXPERIMENT DESIGN CONSIDERATIONS

5.1 Introduction

Chapter Four discussed the design considerations for the experiment and the tool housing the experiment. This chapter elucidates on the actual implementation of both. It will be explained why Visual Basic 6 was selected as the development tool of choice. A few technical details concerning the implementation will be explained in detail. This is followed by an introduction to the two versions of the experiment tools, the lessons learned from the trial run with the prototype and the explanation of the changes based on the lessons learned from that trial run. Finally, the chosen distribution method will be accounted for.

5.2 Development and Software Issues

The decision on which tool to use or custom build as container for the experiment depends on availability, functionality as well as development speed and ease of use of the development software. Any off-the-shelf solution can be ruled out due to the rather unique and specific requirements of the project. From the standpoint of distribution, the most ideal solution to the challenge posed would be a web-based application. However, that type of application does generally not feature all the required capabilities such as the data gathering and log creation potential that is required for the experiment. While it undoubtedly is possible to produce a suitable web-based tool, the issue of the required server-side access rules out this angle of approach. As the time frame for completion was rather short, the best option was found to be Visual Basic 6. While the programming software has limitations, it allows for the swift development of even complex solutions. The potentially greatest drawback in the context of this development effort is that Visual Basic works with components that must be present in the specific Windows environment an application is run on. Unlike in standard C and C++, certain prewritten modules and commands cannot not be compiled into the binary executable through a linker. The individual components instead must be

delivered along with the binary executable through a setup of installation file. The general distribution approach, as will be shown in Section 5.6, already created a number of roadblocks or barriers for the potential participants in the experiment. The need to actually install an application was considered one demand too many and therefore deemed unacceptable.

5.3 Implementation of Tool Requirements

5.3.1 Random Interface and File Names

The tool is set to determine the interface for the knowledge map on start-up of the application. A random number between 1 and 50 is generated. If the number is even, the graphic interface is to be displayed for the exploration and task stages; otherwise the tabular version is presented to the user. It is necessary to make the determination at such an early stage since the result of the determination dictates the name of the output file(s). Two output files are created on start-up. The complexity of the file names is designed to avoid identical file names being produced by two or more participants.

```
Location:      ApplicationPath\supporting_files

Example Graphic Knowledge Map Interface:
Header File:  G_20090728141708_10078442_h.txt
Data File:    G_20090728141708_10078442_d.txt

Example Tabular Knowledge Map Interface:
Header File:  T_20090728141708_10078442_h.txt
Data File:    T_20090728141708_10078442_d.txt
```

The filenames are constructed as follows:

```
Interface Indicator:    G (graphic) or T (tabular)
Date/Time:              System date and time, format YYYYMMDDHHMMSS
Commencement Time:      Milliseconds passed since system boot
File Indicator:         h (summary data), d (data activity log)
File Type:              Text File
```

The data and header files are merged into a single output file when stage six of the experiment is commenced as exemplified in *Figure 5.1*.
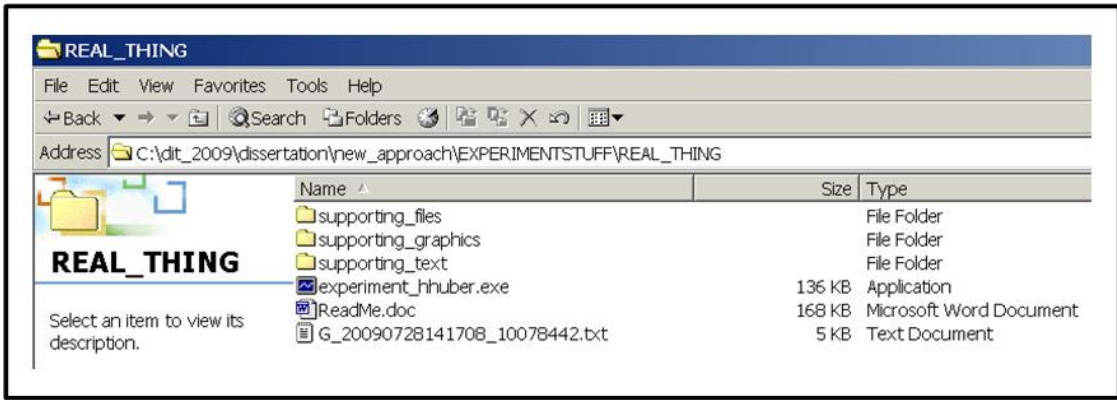
Figure 5. 1: Output File Location

5.3.2 Log Content and Creation

The header section of the log contains the atomic data items listed below.

FileName	Mode	TaskResponse
TaskStatus		
ProjectStart	ProjectCompletion	ProjectDuration
IntroStart	IntroCompletion	IntroDuration
StatsStart	StatsCompletion	StatsDuration
ExplorationStart	ExplorationCompletion	ExplorationDuration
TaskStart	TaskCompletion	TaskDuration
TestStart	TestCompletion	TestDuration

Table 5. 1: LogFile Header Section

The data section of the log is broken down into four individual sections corresponding to the relevant experiment stages.

❑   Statistical Questions

❑   Exploration

❑   Task

❑   Recall Test

During the exploration and task stages the participant's relevant activities are recorded in minute detail. All relevant screen objects are organised in arrays.

❑   The nature of the event.

❑   The object type of the event.

❑   The index of the object allowing the precise determination of the object.

❑   The knowledge base file associated with the object.

❑   Start time of the event in milliseconds.

❑   End time of the event in milliseconds.

❑   Duration of the event in milliseconds as calculated at runtime.

Figure 5.2 provides a sample of such a log. The entries are the result of a sample run-through carried out for the specific purpose of creating an image. The header section is too wide to be displayed in full. Figure 5.2 shows clearly that the design requirements have been fulfilled. The format allows for the quick visual scanning by the human eye and makes the import into any database application easily achievable.

Appendix C provides a full log, as submitted by a participant, for examination.

Figure 5. 2: Log Sample

5.3.3 Application Shells

Figure 5.3 depicts the application shell of the prototype while *Figure 5.4* displays the application shell of the actual experiment tool.
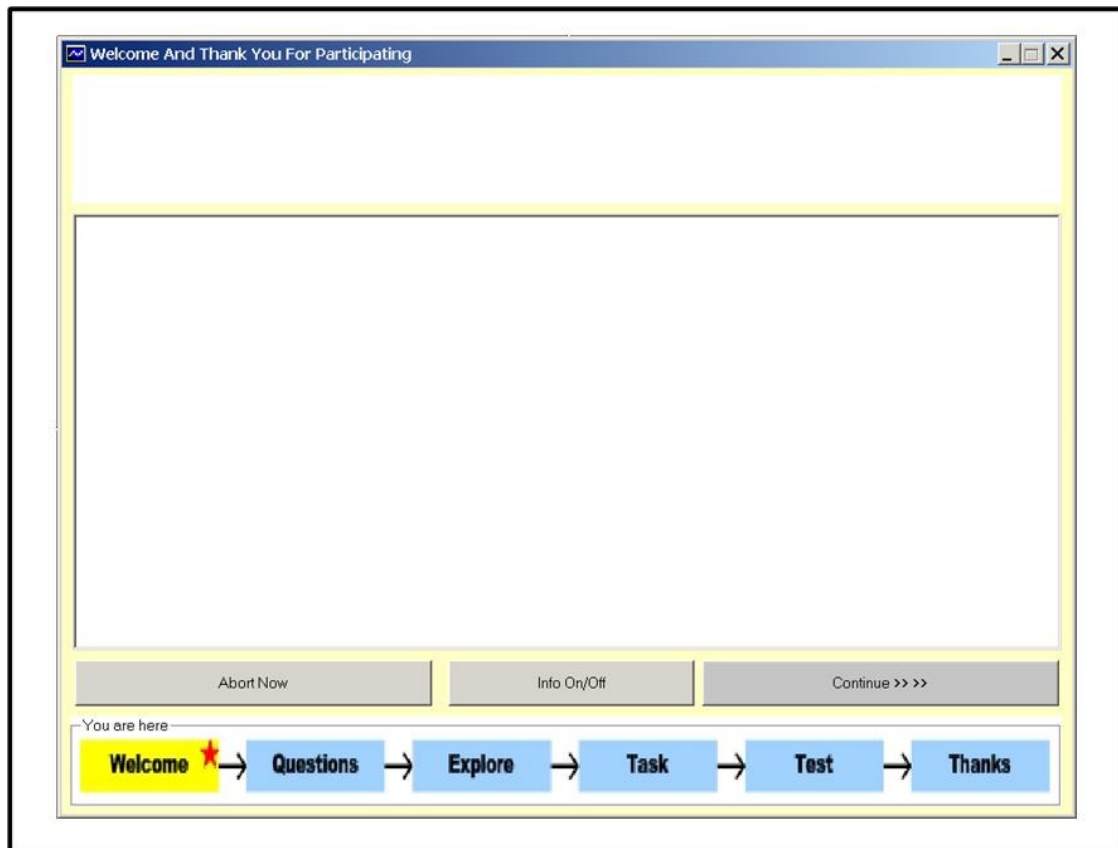
Figure 5. 3: Prototype Application Shell
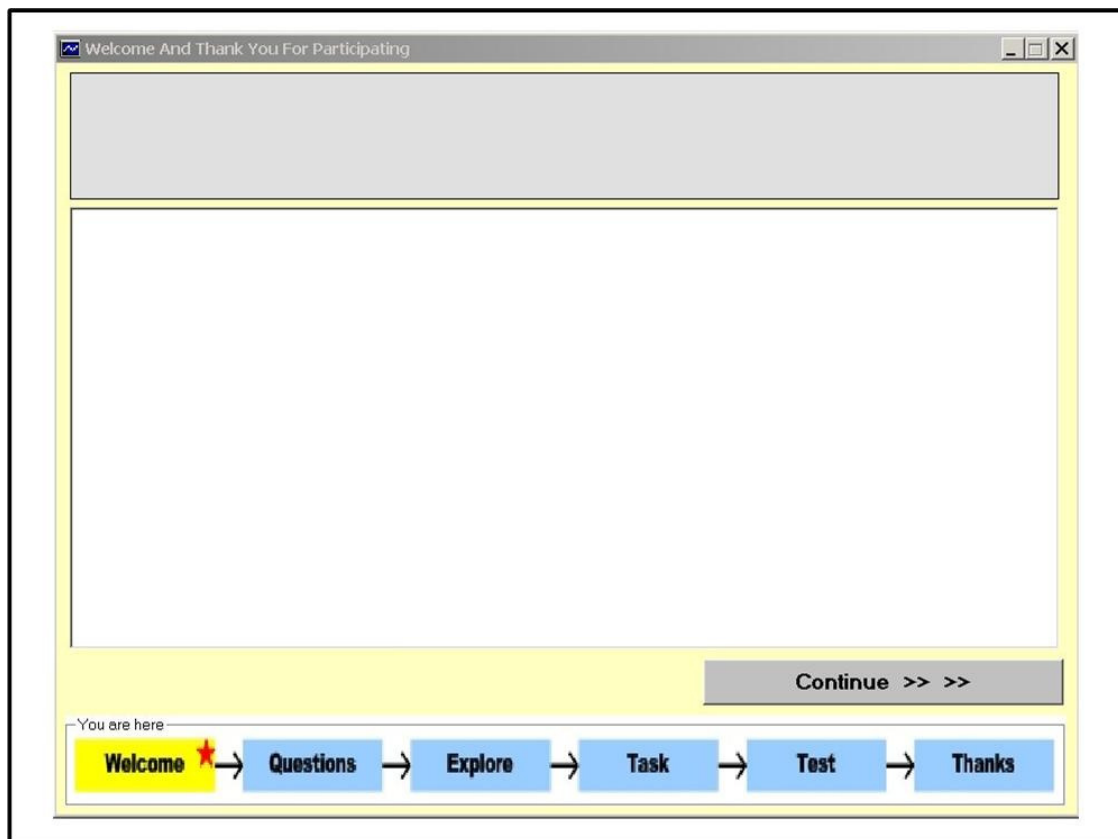
Figure 5. 4: Experiment Tool Application Shell

5.4 *The SECI Prototype*

The experiment and the tool housing it exist in two versions. The first implementation is the prototype while the second was used for the actual experiment. This section elaborates on the prototype.

5.4.1 Topic and Content of the Knowledge Base

The knowledge base of the prototype dealt with the subject of Knowledge Management and the SECI model (Nonaka, 1994) in particular. The four fields of expertise are strictly aligned with the aforementioned model.

- **S**ocialisation
- **E**xternalisation
- **C**ombination
- **I**nternalisation

Area of Expertise	Socialisation	Externalisation	Combination	Internalisation
Expert	Frank Deignan	Deirdre Lawless	Ciaran O'Leary	Damian Gordon
Office	Off Campus	K201	Bride Street	K026A
Tel	+35314022840	+35314022869	+35314024718	+35314022849
Master Concept	**Seminar**	**Systems Analysis**	**Universal Design**	**Learning**
Relationship	Fosters	Concentrates On	Caters	By Doing
Concept	**Interaction**	**Knowledge**	**Expectations**	**Self Learning**
Relationship	Enables	Avoids	Demands	Requires
Concept	**Sharing**	**Bias**	**Flexibility**	**Conceptualising**

Table 5. 2: Knowledge Base Content - SECI Tool

The knowledge flowing into the knowledge base was extracted and sketched during interviews with the experts mentioned above. All the experts are lecturers at the Dublin Institute of Technology.

5.4.2 The Task

The task, as per its design, was to find a single word within a sentence from the knowledge base. The task was posed in the following fashion:

You are now in the task stage. Please find the missing word in this sentence:

The _____ apprenticeship is a good example of this.

You will find the answer in one of the documents you explored at the previous stage. Please type it into the text box that will be provided.

The answer to the task question was to be entered at any stage where a file from the knowledge base had been opened (*Figure 5.5*). The relevant window components were only visible during the task stage.
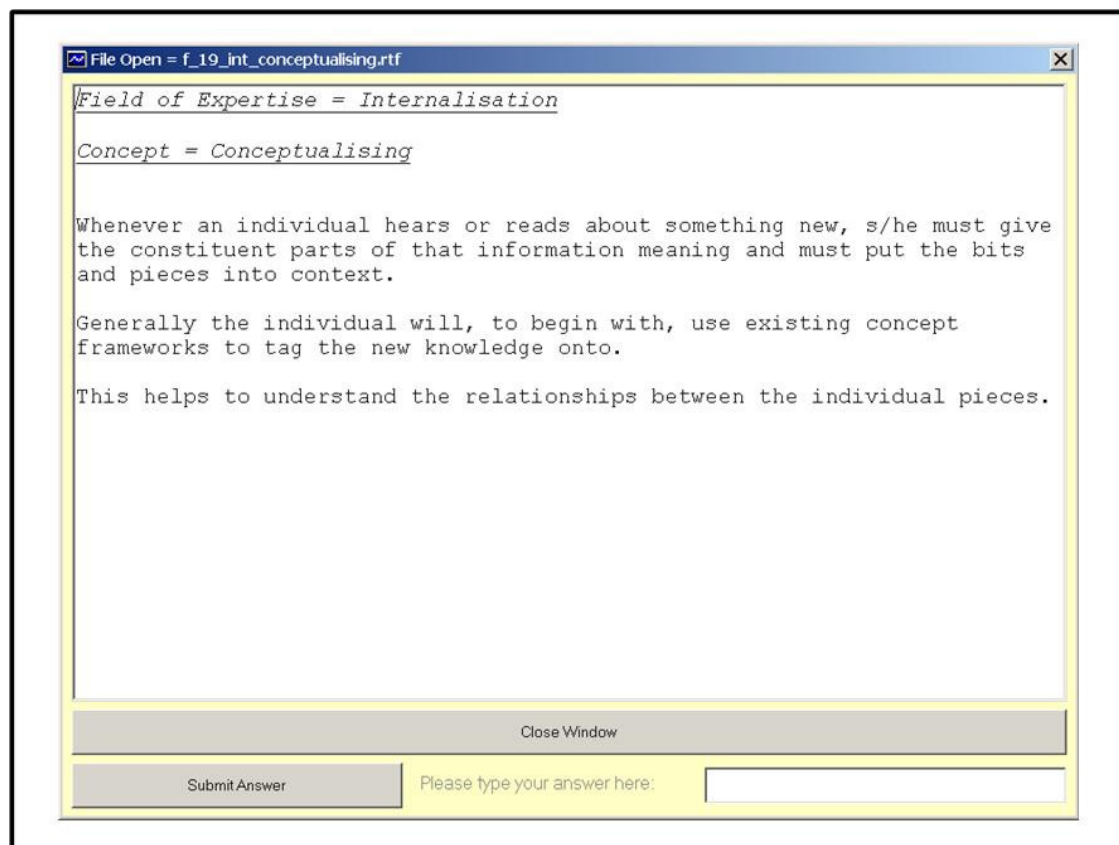
Figure 5. 5: Option to Enter Answer to Task

5.4.3 Recall Test Questions

The recall test questions were implemented precisely along the lines of the design as explained in Section 4.3.1.6.

#	Question	#	Question
1	Who is the expert for Socialisation?	2	Who is the expert for Externalisation?
3	Who is the expert for Combination?	4	Who is the expert for Internalisation?
5	Which expert has his office off campus?	6	Seminars foster what?
7	Universal Design demands what?	8	Knowledge Systems Analysis avoids what?
9	Self-Learning interacts with what?	10	How many areas of expertise were there?

Table 5. 3: Recall Test Questions - SECI Tool

5.4.4 Special Technical Features

The SECI prototype contains three major features that are absent from the actual experiment tool. They implement the requirements as explained in Section 4.3.2.2. These features were abandoned as a result of the trial run.

5.4.2.1 Information Feature

The prototype features a dynamic information capability as illustrated and explained in *Figure 5.6* below. The top window of the tool displays information on specific features and objects on the screen throughout. This is to avoid forcing the participant having to seek document-based help, which placed a considerable burden on the user (Willis, 2006).
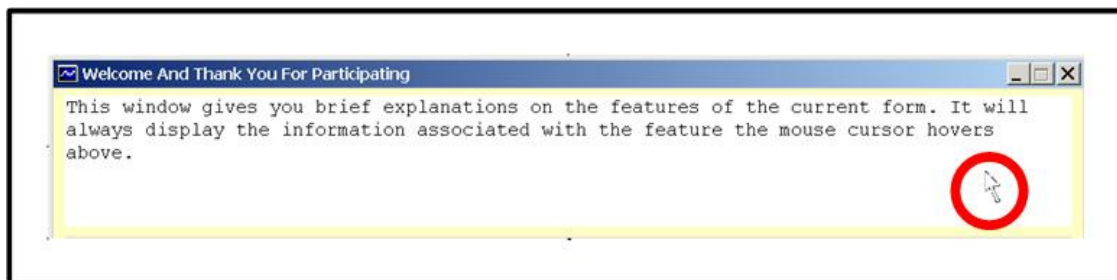
Figure 5. 6: Information Window

This feature can be turned on and off at any stage of the experiment. *Figure 5.7* illustrates the state of the tool with the mouse cursor hovering over the button 'Info On/Off.'
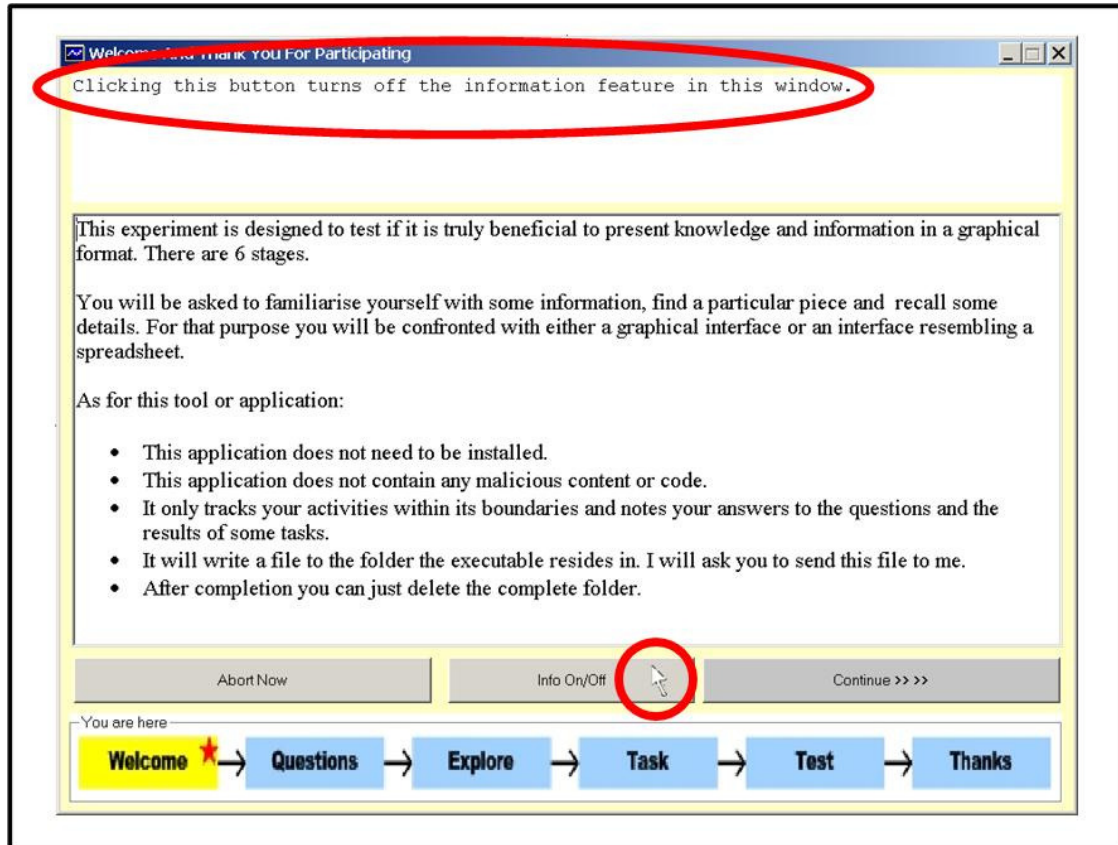
Figure 5. 7: Information Feature On/Off

Figure 5.8 depicts the state of the information window after the user has elected to turn off the information feature.
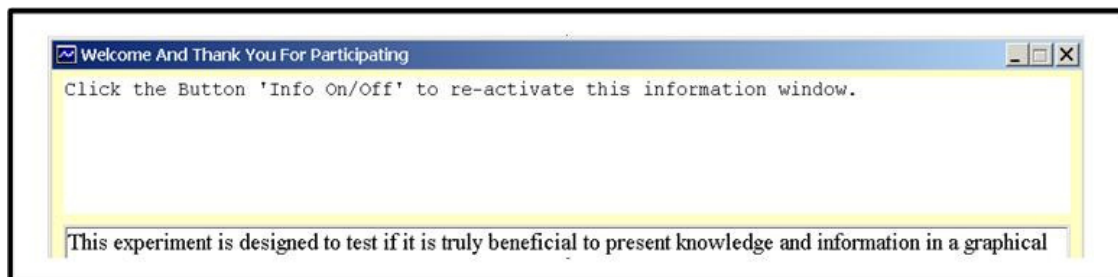
Figure 5. 8: Information Feature Is Off

5.4.2.2   The Abort Feature

The Abort feature, as explained in Chapter Four, is designed to give the user a sense of control over the technology. *Figure 5.9* demonstrates the state of the tool where the mouse cursor hovers over the 'Abort Now' button.
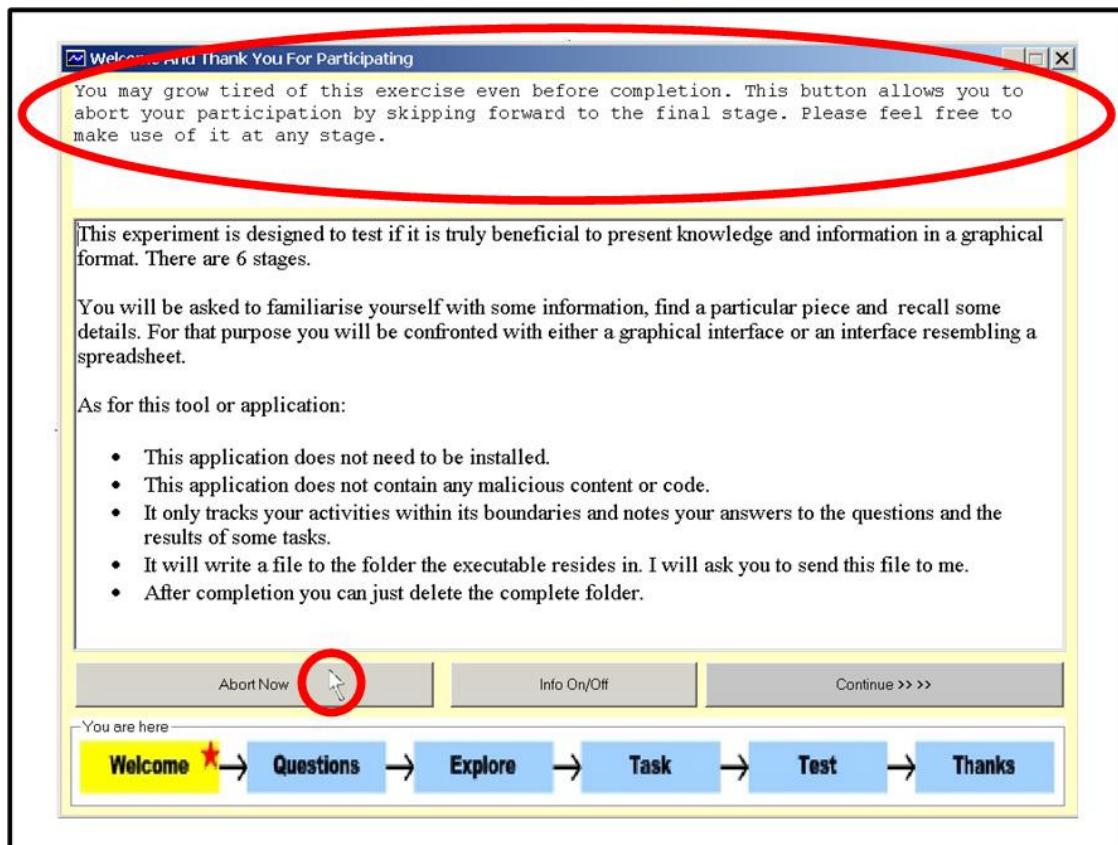
Figure 5. 9: Abort Feature

Figure 5.10 shows the confirmation message box that is displayed to the user after clicks on the 'Abort Now' button.

Figure 5. 10: Abort Confirmation Message Box

Figure 5.11 depicts the final window displayed to the user after electing to abort the experiment process.
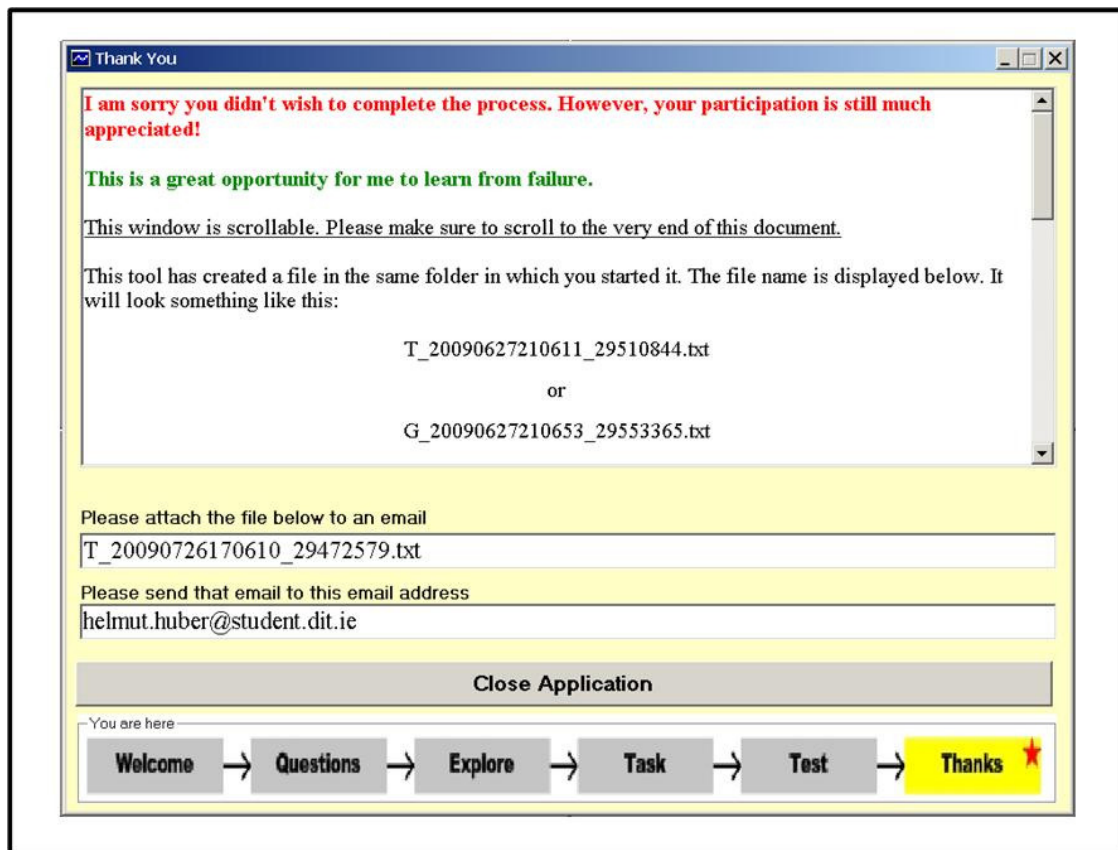
Figure 5. 11: Abort Exit Window

5.4.2.3   Rich-Text-Box Feature

The information and main windows are capable of displaying text in colour and formatted close to the quality of a word processor document. This is achieved through the use of Rich-Text-Boxes, a VB6 component that must be added to the development environment. The relevant component, filename Richtx32.ocx, is one of those components that need to be installed with an application before successful execution can be commenced. It is, however, a common component that is present on many Windows machines already. A test on six individual PCs with varying Windows versions indicated (only 1 PC did not have the component installed already) that, a delivery of the application without the component in question would be a feasible option.

5.5 Trial Run Results

This section presents and discusses briefly the results of and the lessons learned from the trial run, which was conducted using the prototype SECI tool. Seven individual evaluators used the tool and provided their feedback.

5.5.1 Knowledge Base Content

The content of the knowledge base was found to be dry and uninteresting by all seven evaluators. The exercise was considered to be borderline boring.

5.5.2 The Task

The task itself was considered well explained and did not pose a significant challenge. Five evaluators solved the challenge swiftly. One submitted a blank response. The seventh evaluator terminated the execution of the tool out of frustration before reaching the task stage. However, the evaluators agree that the option to enter the answer to the task was not sufficiently marked.

5.5.3 The Recall Test

Four out of the six evaluators reaching this point could answer only Question Ten. The remaining evaluator attempted Question Two only.

5.5.4 Information Feature and Info On/Off Button

There was a consensus that the information provided was too extensive. Instead of informing it served to confuse. As a result, all stepped through the exploration stage too quickly without realising the point of the stage. Only a single evaluator recognised the relationship between the 'Info On/Off' button and the information window. It was turned off after a short while.

5.5.5 The Abort Button

Not a single evaluator noticed the existence of the 'Abort Now' button.

5.5.6 Rich-Text-Box

Six out of the seven evaluators were unable to run the tool at first. The component for the Rich-Text-Box feature was missing from their operating system files. Delivering the missing file was made difficult by the fact that, most email systems consider OCX files as potentially dangerous and block delivery.

5.5.7 Lessons Learned

The results of the trial run and the individual feedback provided by the evaluators make it clear that significant changes needed to be made. A new topic was required. The KM specific content of the knowledge base was not important for the purpose of the experiment. Dropping it did not cause any issues. The tool interface was too heavy and needed to be scaled sown.

- A new way to enter the answer to the task was required.
- The information window was made static, holding only one piece of information per experiment stage.
- The 'Info On/Off' button was removed.
- The 'Abort Now' button was removed.
- Standard text boxes replaced the Rich-Text-Boxes.

5.6 The Live (Sauerkraut) Tool

The Sauerkraut tool is the result of the lessons learned from the trial run with the SECI tool. It shares the backend features with the latter but is a stripped-down version in terms of tool interface.

5.6.1 Topic and Content of the Knowledge Base

The Sauerkraut tool derives its name from the topic its knowledge base deals with. The chosen topic, outside the Germanic countries, is reasonably obscure so that it might feature a certain fun factor and generate some interest. The overall subject was divided up into four different areas of expertise, assigned fictitious experts and specific concepts. The details of the resulting knowledge base may be explored in *Table 5.2*.

Area of Expertise	Growing Cabbage	Cutting Cabbage	Seasoning Cabbage	Curing Sauerkraut
Expert	Joe Harvester	Jack Blade	Lucy Spice	Hans Barrel
Office	Mullingar	Berlin	Salzburg	Munich
Tel	+3534477777	+4930999999	+432667111111	+49890555555
Master Concept	The right cabbage	Manual Cutting	Seasoning	Curing
Relationship	needs	right amount of	requires little	takes
Concept	Rain	Pressure	Salt	Time
Relationship	is harvested	demands	is done by	calls for
Concept	Summer	Rhythm	Layers	Environment

Table 5. 4: Knowledge Base Content - Sauerkraut Tool

❑ The expert's names are fictional and fashioned to be memorable.

❑ The locations of the fictional offices are designed to be easily included into the associative chain of the viewer.

❑ The international and area codes in the telephone numbers are correct while the connection numbers are fictional.

❑   The concepts and relationships between the concepts are correct and based on years of experience in the making of sauerkraut.

The precise content of the knowledge base as presented to the participants may be examined in Appendix A.

5.6.2 The Task

Participants were asked to find a single word that is contained within a sentence from the knowledge base. The task question is presented in the following format.

"***Your task is to find a single word. It is the missing word in following sentence:***

The _____ needs to be replaced regularly."

The sentence is part of the knowledge base entry on the main concept of the field *Curing Sauerkraut*. It is expected that both groups perform in and around the same level. The tabular group could outperform the graphic group since all information is accessible from one single screen. The table layout and the information contained must within itself convey some semantic meaning. Otherwise the graphic group would have a significant advantage that in turn would introduce a bias fit to invalidate the whole experiment.

5.6.3 The Recall Test

Each Participant was asked 10 questions about information contained in the interface and the knowledge base.

#	Question	#	Question
1	How many areas of expertise were there?	2	Who is the expert for growing cabbage?
3	Who is the expert for cutting cabbage?	4	Who is the expert for curing sauerkraut?
5	Who has an office in Munich?	6	Who has an office in Salzburg?
7	Whose phone number is +3534477777?	8	Are onions an ingredient for sauerkraut?
9	Does sauerkraut require lots of salt?	10	What is the best season to harvest cabbage?

Table 5. 5: Recall Test Questions - Sauerkraut Tool

The nature and sequence of the questions is based on the lessons learned from the trial run using the prototype. Question one serves to ease the participant into the process of taking a kind of test. It is not too a difficult question and should be fair to both groups. It is expected that questions two through to six will produce a difference in outcome. Reason being is that, the graphic group receives visual cues that are not available to the group presented with the tabular interface. Questions 8, 9 and 10 are about the content of the actual knowledge base. The outcome is expected to depend on the individual depth of the exploration of the knowledge base. The questions have been chosen to cover the whole spectrum.

5.6.4 Sauerkraut Tool Screen Shots

Figures 5.13 and *5.14* depict the relevant Knowledge Map interfaces of the sauerkraut tool. *Figures 5.15* to *5.20* provide images of a sequential run through the entire experiment as experienced by any participant. The individual items in each image are to be viewed from left to right and top to bottom. The changes made after the trial run with the SECI prototype are clearly visible.

Figure 5. 12: Graphic Knowledge Map Interface

Figure 5. 13: Tabular Knowledge Map Interface
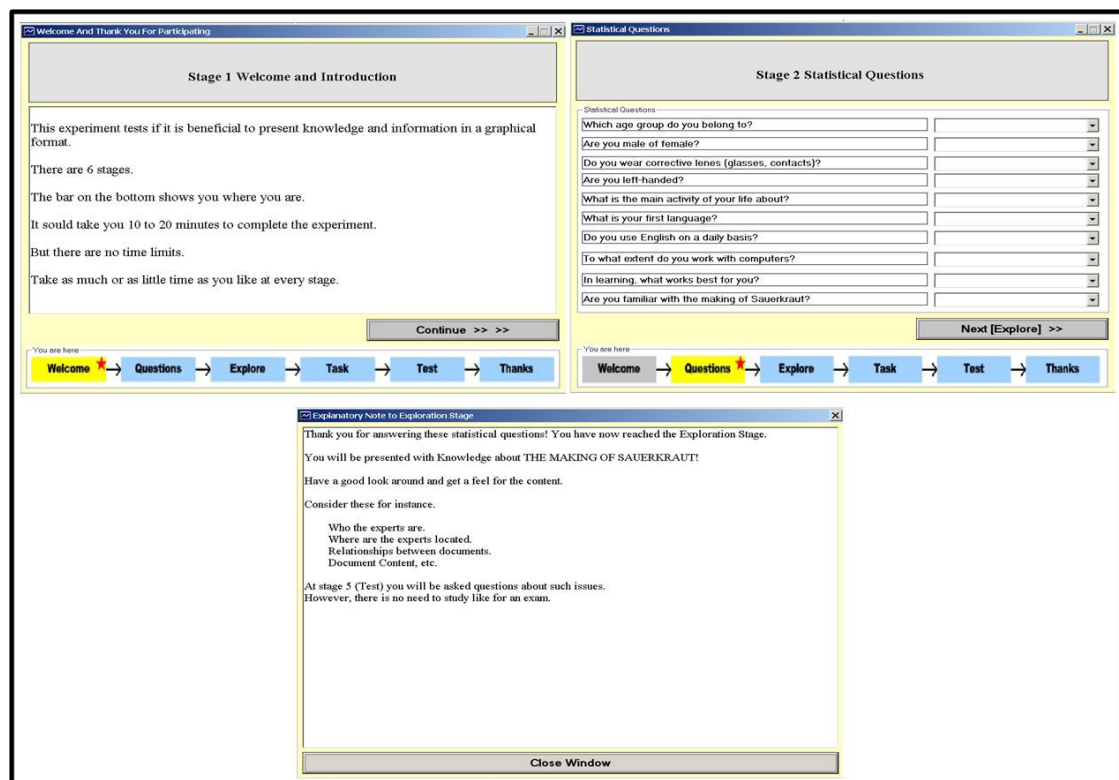
Figure 5. 14: Welcome & Statistical Question Stages
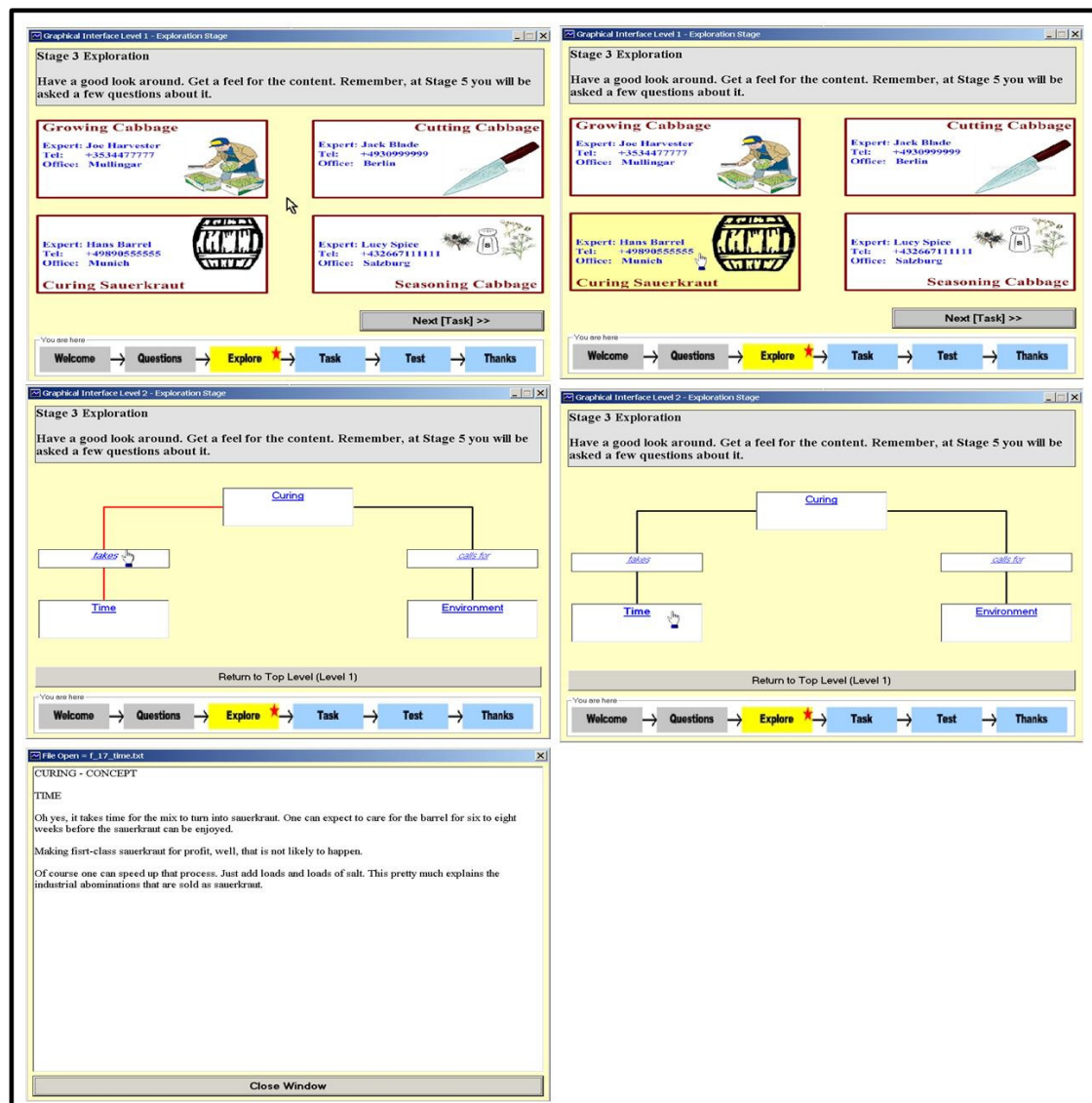
Figure 5. 15: Exploration Stage - Graphic Knowledge Map
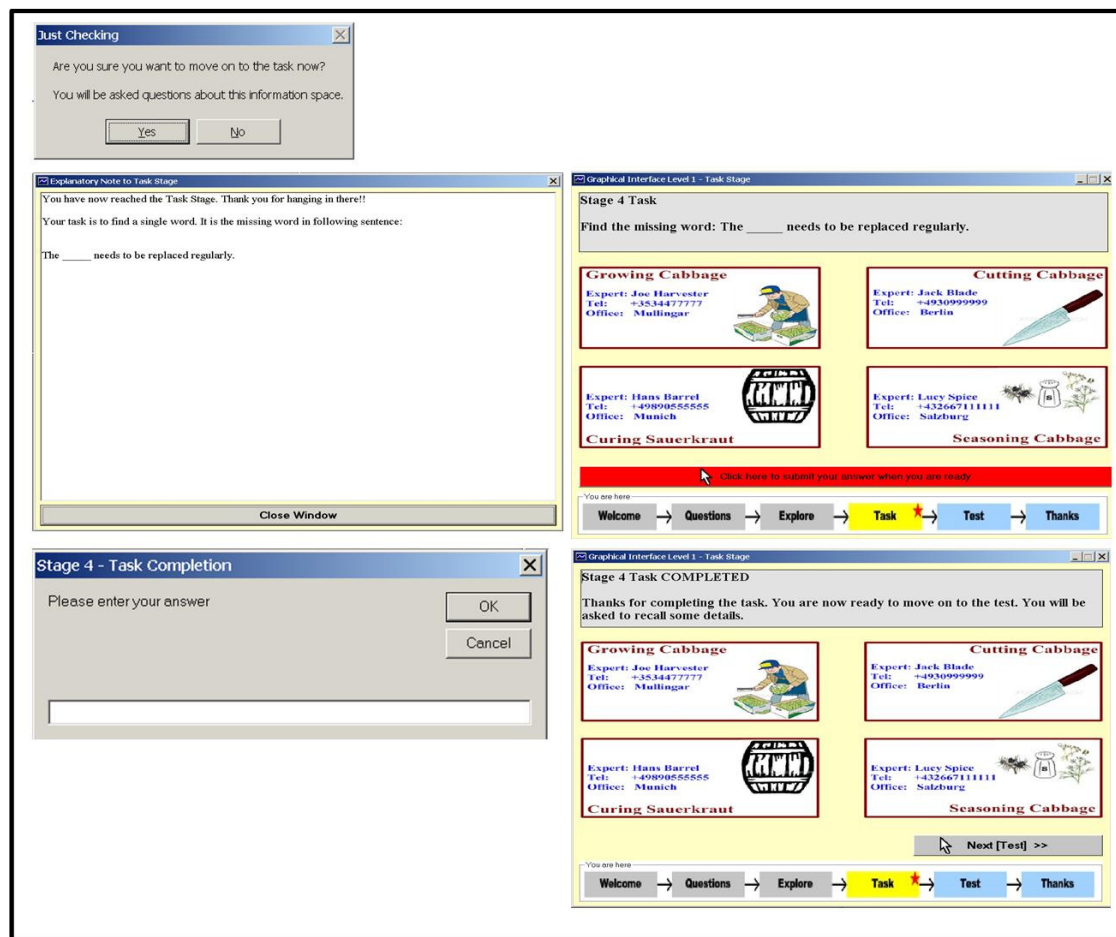
Figure 5. 16: Task Stage - Graphic Knowledge Map
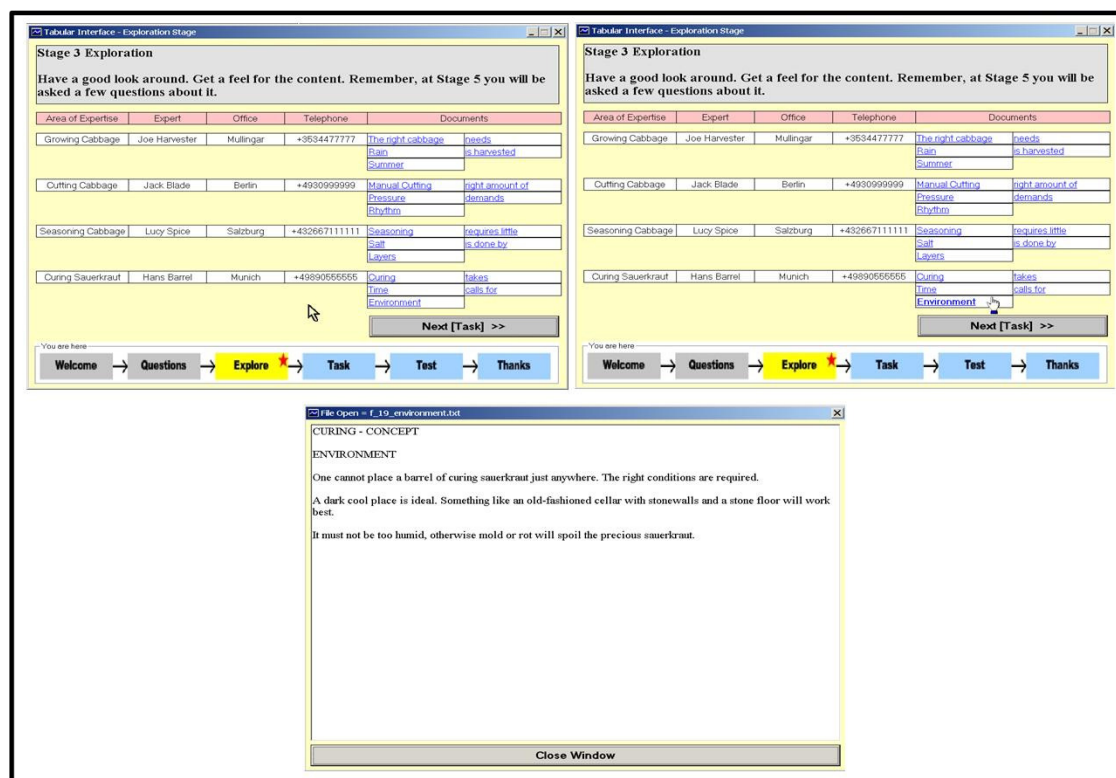
Figure 5. 17: Exploration Stage - Tabular Knowledge Map
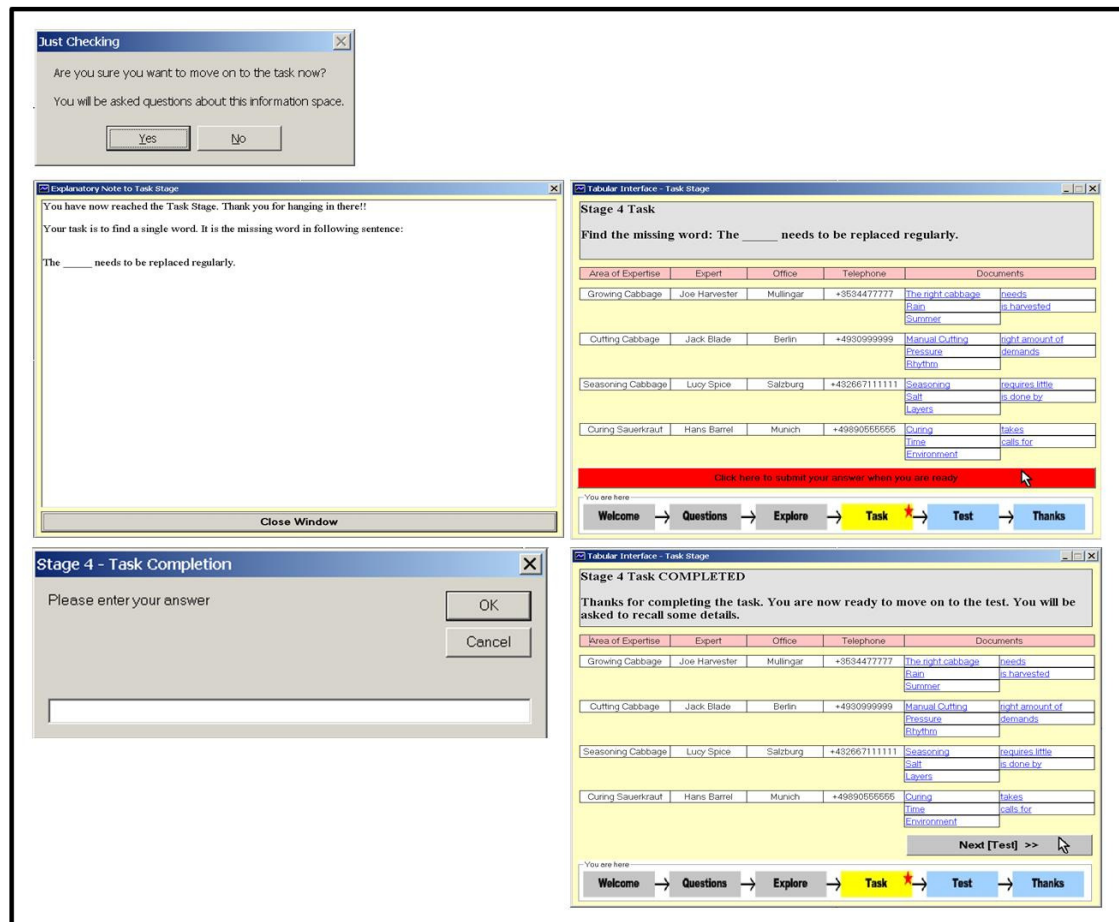
Figure 5. 18: Task Stage - Tabular Knowledge Map
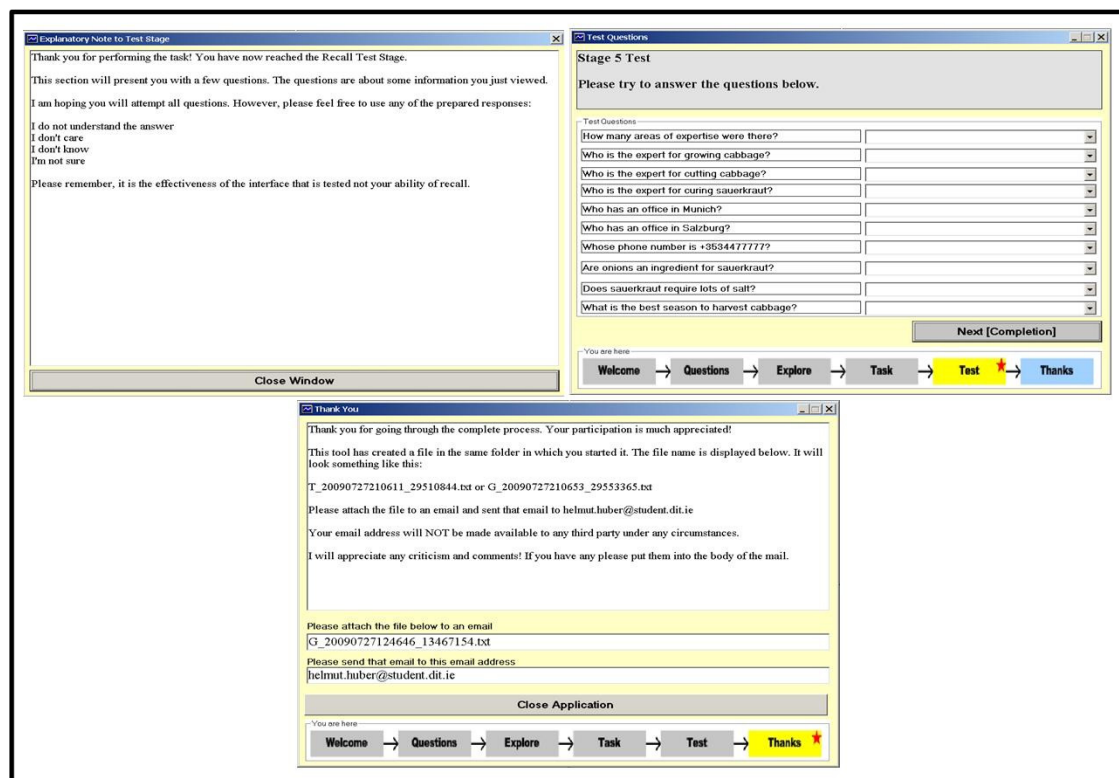
Figure 5. 19: Test & Closure Stages

5.7 Distribution Implementation

The decision was taken to zip the tool and all supporting files (76 individual files) along with an explanatory ReadMe.doc into one ZIP file and place it onto a website for distribution. The DIT website of Damian Gordon, who supervised the project, was deemed to be the most suitable location. It was reasoned that individuals would be more at ease with a source coming from within a reputable institution.

Emails pointing to that website were sent out in accordance with the design as laid out in Section 4.4.

- ❑   5 Requests to the individuals who had agreed in advance to be the primary distribution nodes.
- ❑   52 Requests for individual participation to friends, acquaintances and fellow students.
- ❑   344 Requests (in bulk, one or two per institution) to Computer Science lecturers in Ireland.

5.7.1 Benefits of the Approach

The chosen approach allows for the gathering of useful and detailed qualitative data. One of the research goals is to get an understanding of users' behaviour. The extensive log file created by the tool achieves this.

The distribution approach as illustrated in Figure 4.12 has the potential to gather data generated by a very diverse group of individuals with very different backgrounds. This may serve to reflect the disparate nature of the workforce found in the modern organisation.

5.7.2 Barriers Created by the Approach

It is acknowledged that, participation in the experiment cannot be considered easy and straightforward.

❑ Participants have to read an email that cannot be considered brief.
❑ Participants need to access a website.
❑ Participants have to download a file with unknown content.
❑ Participants have to unpack the file with unknown content.
❑ Participants need to run a program.

The greatest barrier is the need to download and execute a program. It was expected that a good number of interested people would shy away from participation for that reason only. This must be accepted since the chosen approach is the only really viable option to achieve the set goals. The line that could not be crossed was the requirement for participants to install a program. It was reasoned that such a requirement would reduce participation to practically zero. Features like the option of automated FTP submission or email generation were also omitted for the same reason. Details of the distribution approach can be viewed in Appendix B.

5.8 Conclusions

This chapter elaborated on the implementation of the experiment itself and the tool housing it. The point was made that Visual Basic 6 was selected as the development tool of choice since it allows for the swift development of applications and is capable of producing the kind of experiment log that is required for this type of experiment. Two versions of experiment and tool were introduced. The most vital technical features like file name generation and log file generation have been explained. Detailing the development of a prototype for a trial run followed. It was shown how the experiences and lessons learned from that trial run fed into the development of the actual experiment. Finally, the distribution method was explained and justified. Chapter Six will present and discuss the findings of the experiment.

6 EXPERIMENTATION & EVALUATION

6.1 Introduction

Chapter Five dealt with issues and lessons on the experiment implementation. This chapter will present issues arising from the experimentation process and the findings of the experiment itself. The results are produced and discussed. It will be found that no statistical significance could be found to support the hypothesis that a graphical knowledge base interface will facilitate better recall in individuals than a tabular interface. However, it will be found that the experiment succeeded in three of the four objectives and that the data gathers holds valuable qualitative results.

6.2 Issues Encountered During Distribution

A good number of issues and problems were encountered during the distribution and the execution of the experiment.

❑ Participation in the experiment was low and yielded only 24 usable datasets.

❑ The approach of the primary distribution nodes did not function as envisioned. Only one of the nodes did produce the kind of returns it was hoped for.

❑ Seven potential participants made contact by email pointing out the fact that, they were not using any operating systems of the Windows family. These individuals were excluded despite their interest and willingness to participate.

❑ Many participants had great difficulties handling the ZIP file. Much time and effort had to be expended in the effort to support participants who experienced that particular problem. Five potential participants, who initially made contact by email reporting problems relating to the unpacking of the download, were eventually lost to the experiment.

6.3 Overview on Participants' Statistical Data

This section provides an overview on the responses given by the participants to the 10 statistical questions. *Figure 6.1* holds the data in tabular format. *Figure 6.2* through to *Figure 6.11* provide the same data in graphical format.

Q 1

Mode	Which age group do you belong to?	Count
Graphic	21 - 30	6
Graphic	31 - 40	3
Graphic	41 - 50	2
Tabular	21 - 30	3
Tabular	31 - 40	6
Tabular	41 - 50	3
Tabular	61 - 70	1

Q 2

Mode	Are you male of female?	Count
Graphic	Female	5
Graphic	Male	6
Tabular	Female	4
Tabular	Male	9

Q 3

Mode	Do you wear corrective lenses (glasses, contacts)?	Count
Graphic	No	6
Graphic	Yes	5
Tabular	No	7
Tabular	Yes	6

Q 4

Mode	Are you left-handed?	Count
Graphic	No	9
Graphic	Yes	2
Tabular	No	13
Tabular	Yes	0

Q 5

Mode	What is the main activity of your life about?	Count
Graphic	Dealing with Data or Numbers	4
Graphic	Dealing with People	1
Graphic	Handling Technology (Computing)	3
Graphic	Leading/Motivating People	2
Graphic	Teaching People	1
Tabular	Dealing with Data or Numbers	3
Tabular	Handling Technology (Computing)	4
Tabular	Handling Technology (Other)	2
Tabular	Studying Humanities	1
Tabular	Studying Sciences	1
Tabular	Teaching People	2

Q 6

Mode	What is your first language?	Count
Graphic	English	5
Graphic	German	2
Graphic	Irish	1
Graphic	Italian	1
Graphic	Polish	1
Graphic	Slovak	1
Tabular	Czech	1
Tabular	English	8
Tabular	German	4

Q 7

Mode	Do you use English on a daily basis?	Count
Graphic	At work only	1
Graphic	Exclusively	6
Graphic	Mostly	3
Graphic	Practically never	1
Tabular	Exclusively	8
Tabular	In social interactions mostly	1
Tabular	Mostly	1
Tabular	Practically never	2
Tabular	Rarely	1

Q 8

Mode	To what extent do you work with computers?	Count
Graphic	At home constantly	2
Graphic	At work constantly	4
Graphic	Constantly at work and at home	5
Tabular	At home constantly	1
Tabular	At home occasionally	1
Tabular	At work constantly	3
Tabular	Constantly at work and at home	8

Q 9

Mode	In learning, what works best for you?	Count
Graphic	A Combination of Both	7
Graphic	Text-Based Material	1
Graphic	Visual Material	3
Tabular	A Combination of Both	12
Tabular	Text-Based Material	1

Q 10

Mode	Are you familiar with the making of Sauerkraut?	Count
Graphic	Never heard of it	3
Graphic	Somewhat familiar with it	7
Graphic	Very familiar with it	1
Tabular	Somewhat familiar with it	9
Tabular	Very familiar with it	4

Figure 6. 1: Summary of Responses to Statistical Questions
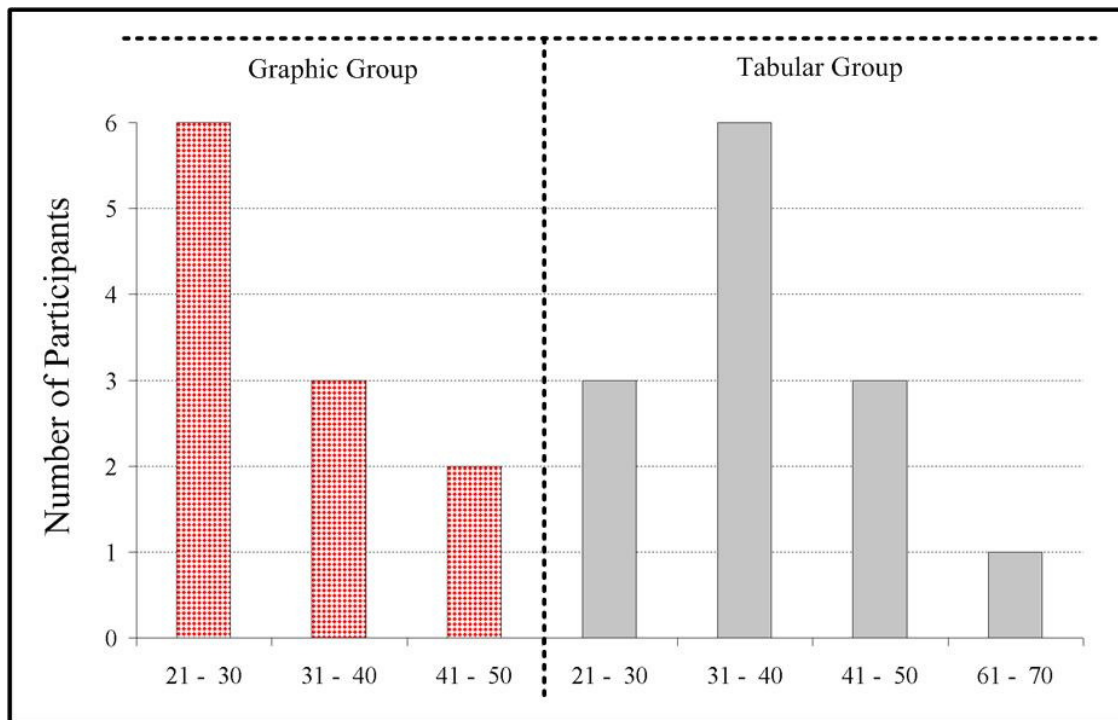
Figure 6. 2: Chart [Which age group do you belong to?]
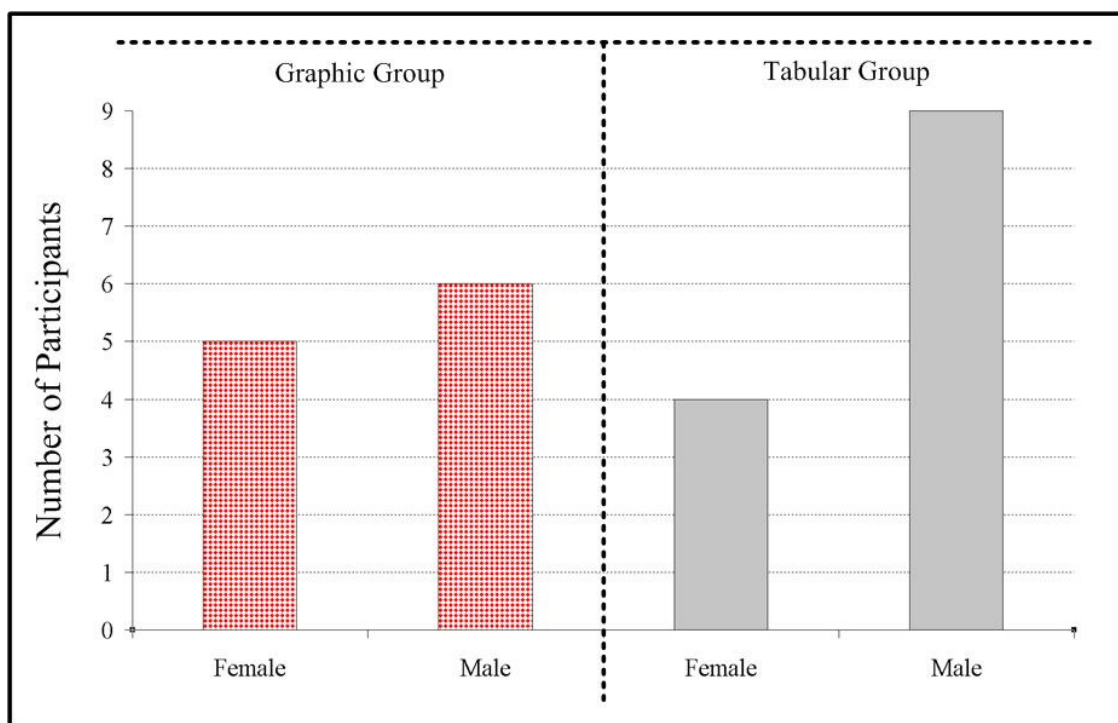
Figure 6. 3: Chart [Are you male of female?]
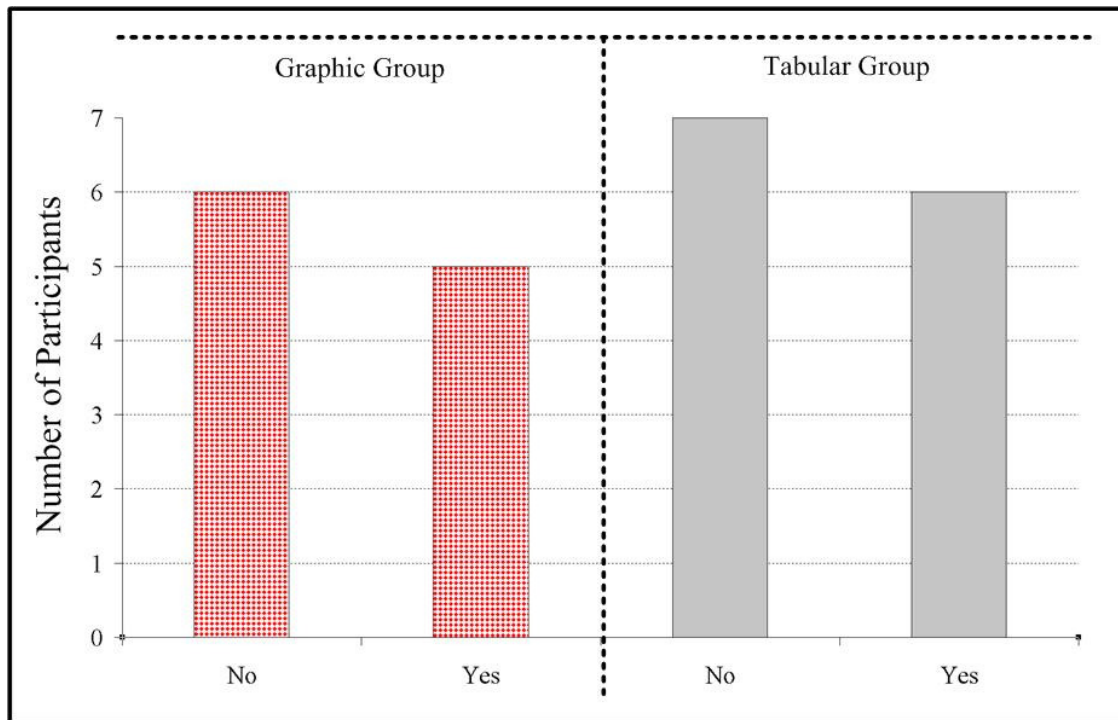
Figure 6. 4: Chart [Do you wear corrective lenses (glasses, contacts)?]
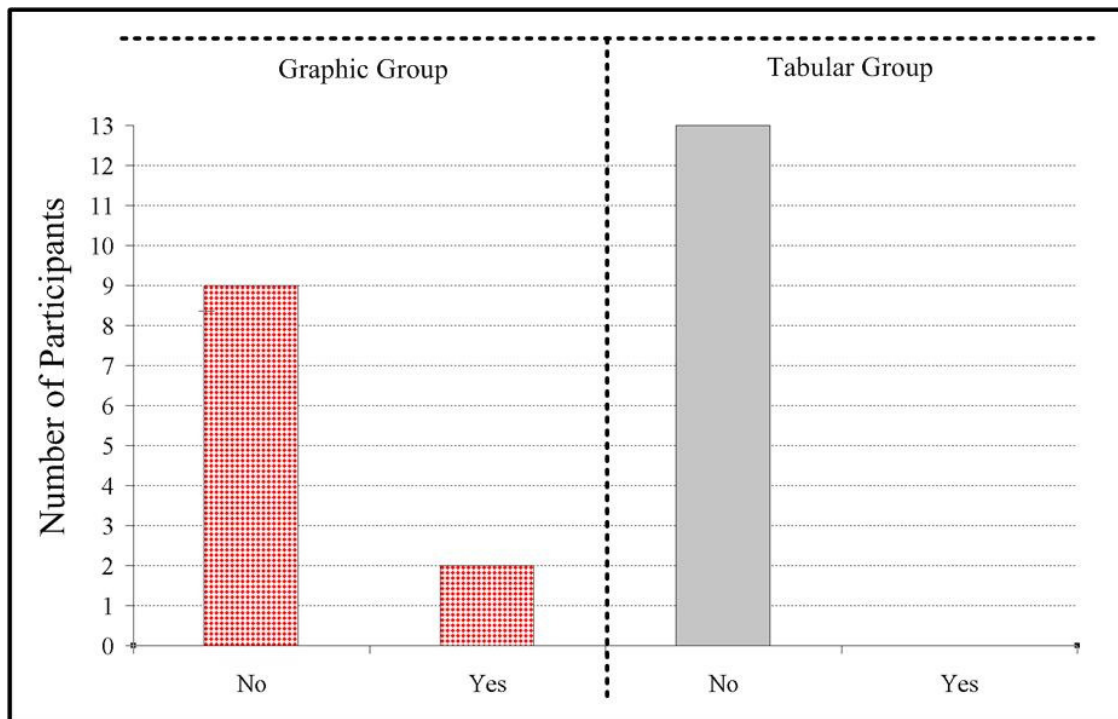
Figure 6. 5: Chart [Are you left-handed?]
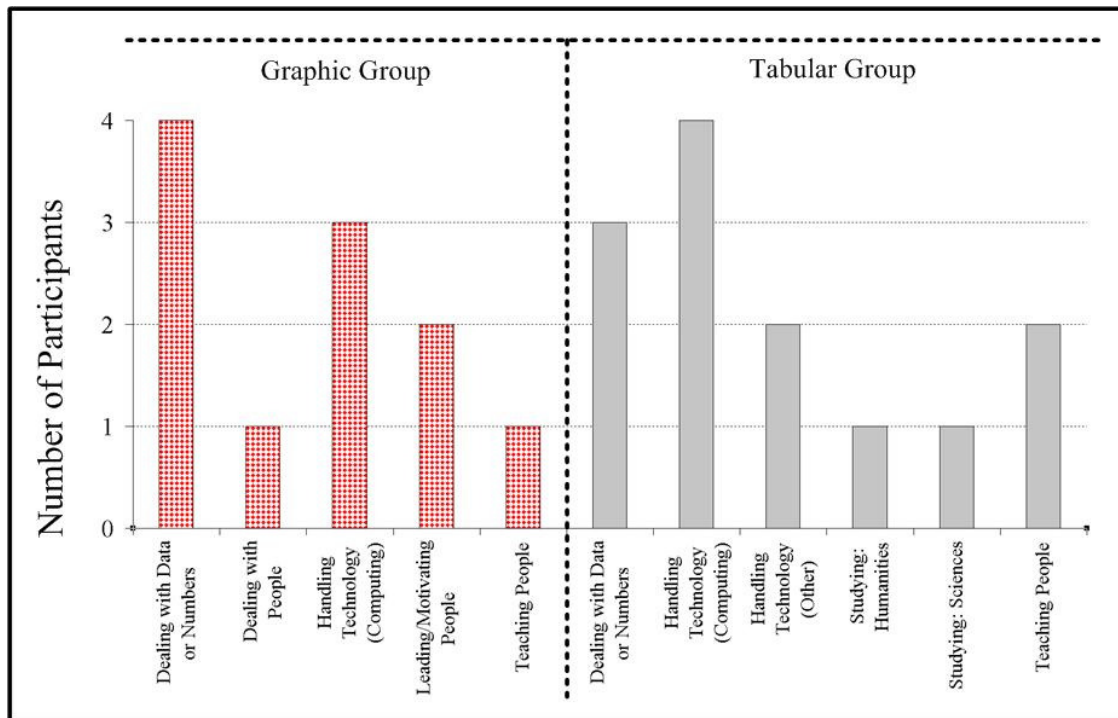
Figure 6. 6: Chart [What is the main activity of your life about?]
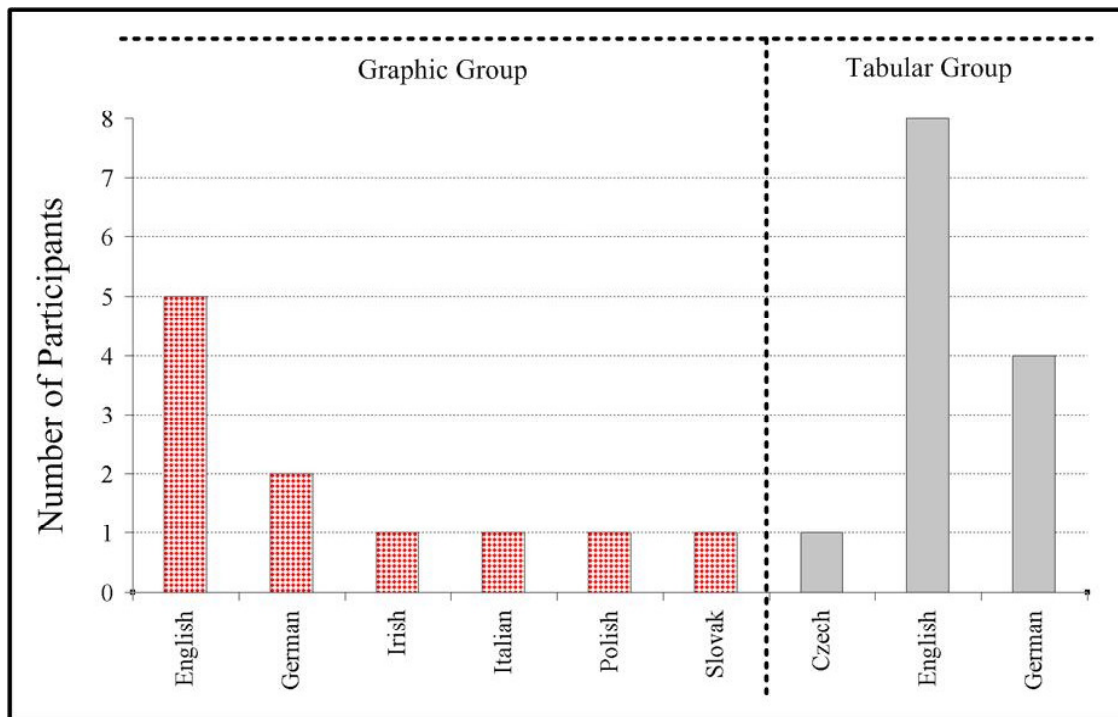
Figure 6. 7: Chart [What is your first language?]
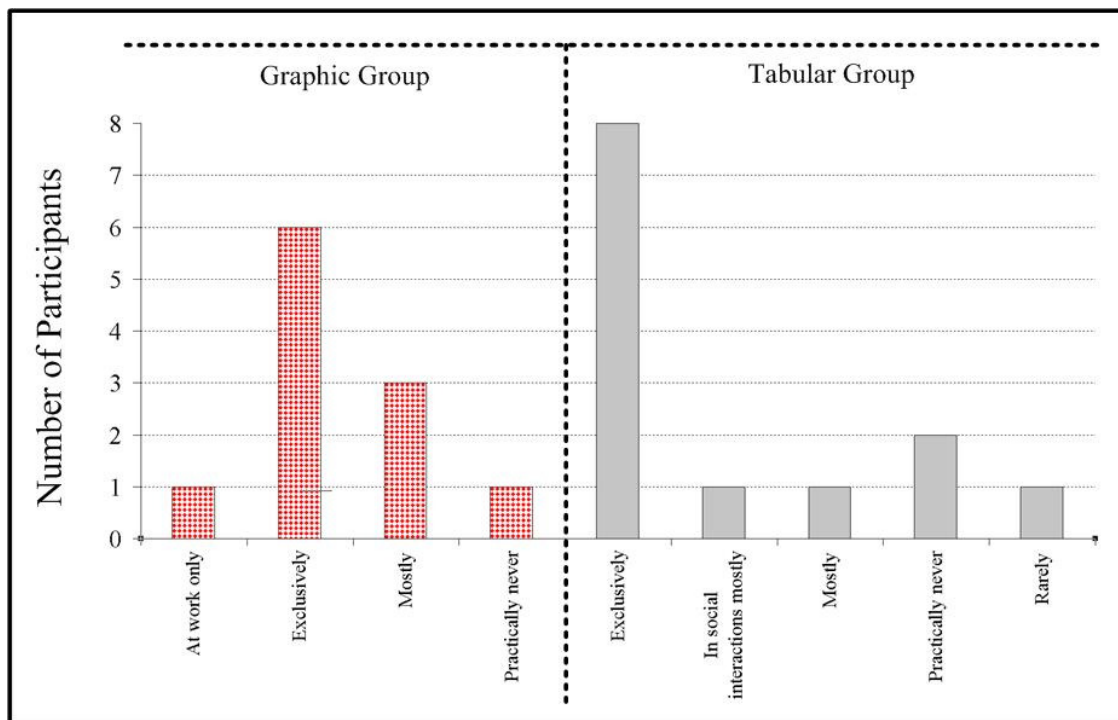
Figure 6. 8: Chart [Do you use English on a daily basis?]
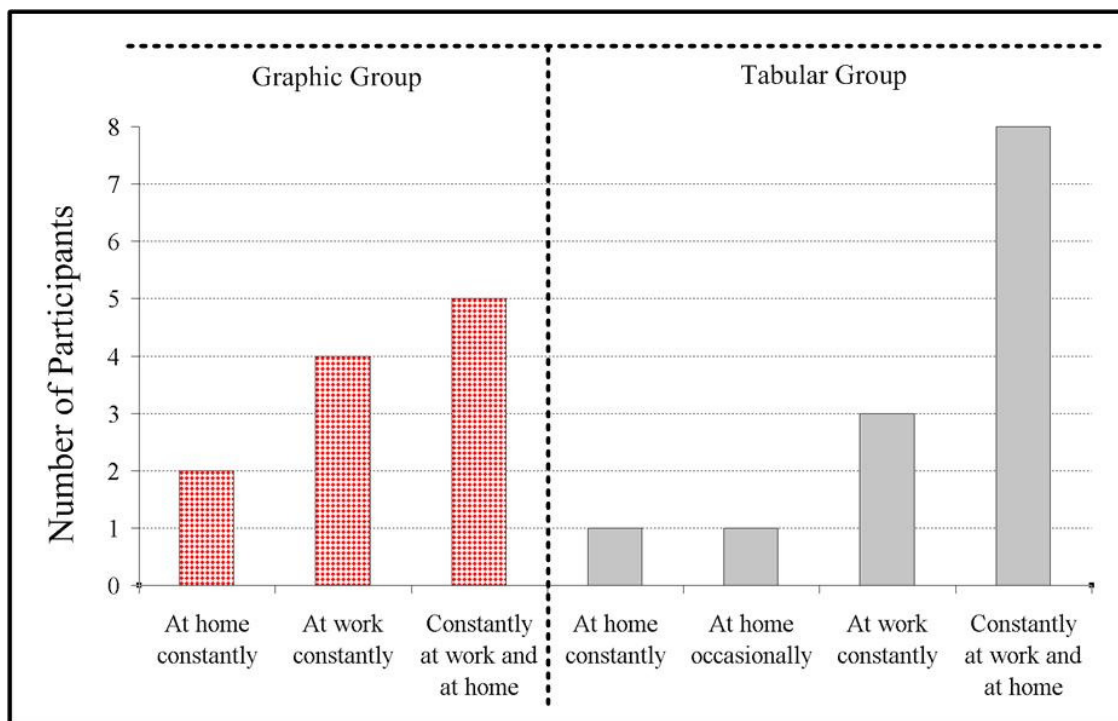
Figure 6. 9: Chart [To what extent do you work with computers?]

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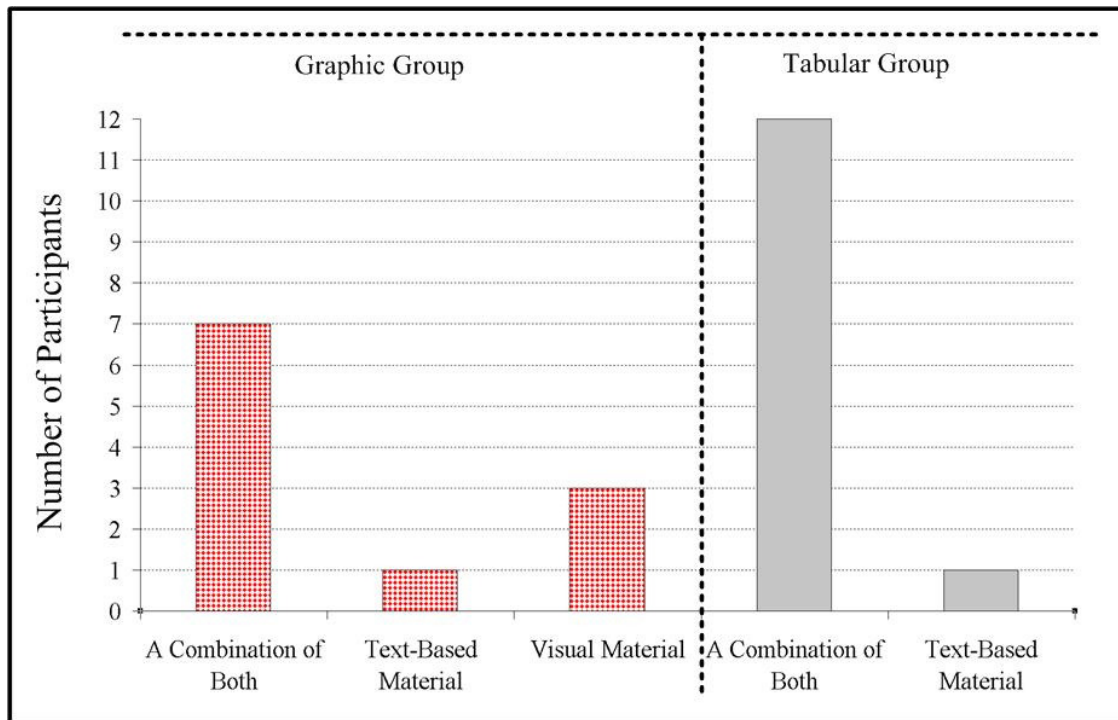
Figure 6. 10: Chart [In learning, what works best for you?]
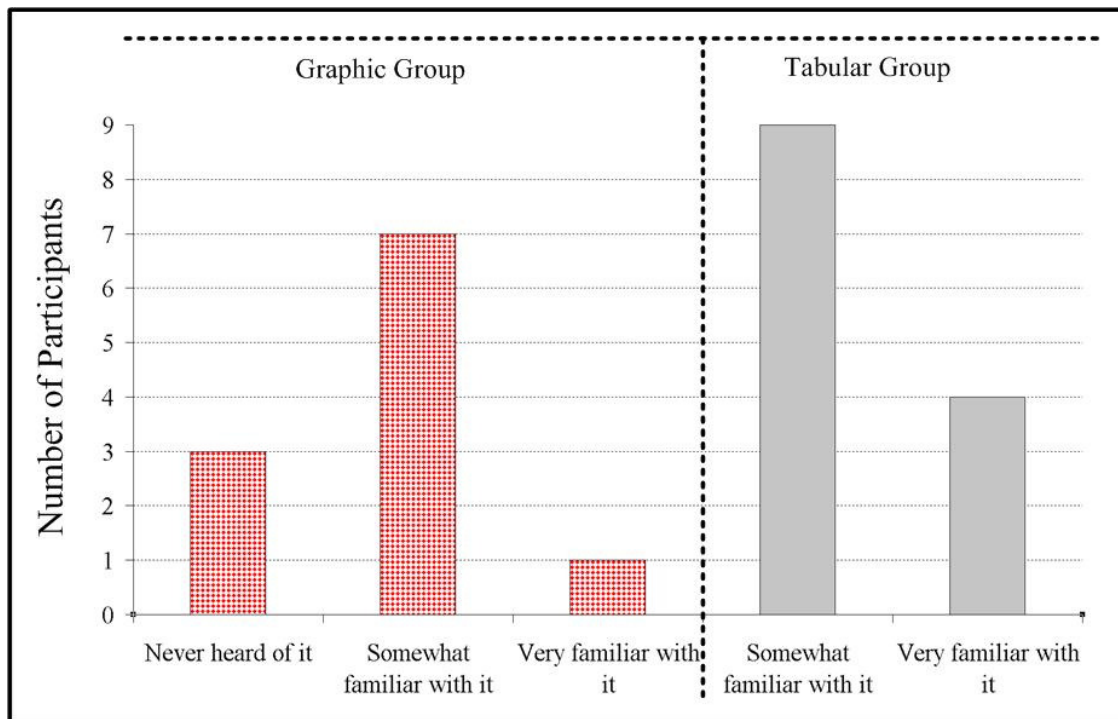
Figure 6. 11: Chart [Are you familiar with the making of sauerkraut?]

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6.4 Quantitative Results

6.4.1 Task Results

Table 6.1 presents the results of the experiment task. Correct answers are represented by 1, incorrect answers by 0.

ParticipantNumber	Mode	Task	ParticipantNumber	Mode	Task
1	Graphic	1	5	Tabular	0
2	Graphic	0	6	Tabular	0
3	Graphic	0	7	Tabular	1
4	Graphic	0	8	Tabular	1
12	Graphic	0	9	Tabular	1
13	Graphic	1	10	Tabular	0
14	Graphic	1	11	Tabular	0
16	Graphic	0	15	Tabular	1
19	Graphic	0	17	Tabular	0
21	Graphic	0	18	Tabular	1
24	Graphic	0	20	Tabular	0
			22	Tabular	0
			23	Tabular	0
	Sum	**3**		**Sum**	**5**
	Avg	**0.27273**		**Avg**	**0.45455**

Table 6. 1: Results of Experiment Task

The dataset, due to the small sample size and the nature of the results, does not warrant any statistical analysis. H_0 is accepted.

6.4.2 Recall Test Results

6.4.2.1   Awarding Marks to Answers

Each answer to the recall test was assigned an individual mark. In doing so a differentiation was made between questions related to the content of the knowledge base and questions related to the interface of the knowledge map. *Table 6.2* reiterates the recall test questions as per Section 4.3.1.6.

#	Question	#	Question
1	How many areas of expertise were there?	2	Who is the expert for growing cabbage?
3	Who is the expert for cutting cabbage?	4	Who is the expert for curing sauerkraut?
5	Who has an office in Munich?	6	Who has an office in Salzburg?
7	Whose phone number is +3534477777?	8	Are onions an ingredient for sauerkraut?
9	Does sauerkraut require lots of salt?	10	What is the best season to harvest cabbage?

Table 6. 2: Recall Test Questions

This differentiation resulted in the two groups of questions and answers as introduced below.

❑ **KB (Knowledge Base Questions)**: Questions 1, 8, 9, 10 are considered to be strongly related to the content of the knowledge base. The questions are relatively simple in nature. The chosen marking approach for the answer therefore is also simple.

▪ Correct answers were awarded 1 mark. Otherwise 0 marks were awarded.

❑ **KMI (Knowledge Map Interface Questions):** Questions 2, 3, 4, 5, 6, 7 are considered to be strongly related to the type of the knowledge map (graphic, tabular) presented to the individual participant. The questions are more complex in nature and allow for a greater variety of types of answers. Marks therefore were awarded on a sliding scale from 0 to 4.

- 4 marks were awarded for a perfectly correct answer. 3 marks were awarded for an almost perfect answer. 2 marks were awarded for a half correct answer. 1 mark was awarded for a wrong answer, which still indicated that the participant had retained something relevant. 0 marks were awarded for any wrong answer. *Table 6.2* provides some representative examples for this approach.

Original Question	Correct Answer	Sample Answer	Mark Assigned
Who has an office in Salzburg?	Lucy Spice	Lucy Spice	4
Who has an office in Salzburg?	Lucy Spice	Spice Lucy	4
Who has an office in Salzburg?	Lucy Spice	Lucy Spyce	3
Who is the expert for curing sauerkraut?	Hans Barrel	Hans Barrell	3
Who has an office in Salzburg?	Lucy Spice	Lucy	2
Who is the expert for cutting cabbage?	Jack Blade	Blade	2
Who is the expert for growing cabbage?	Joe Harvester	Mr Harvester	2
Who is the expert for growing cabbage?	Joe Harvester	Person living in Ireland	1
Who has an office in Munich?	Hans Barrel	The expert in curing	1

Table 6. 3: Examples of KBI Marking Approach

In addition to the marks awarded, all 10 answers received a *Correctness Indicator* of either 1 (correct) or 0 (incorrect). No differentiation between the question/answer types KB and KMI was made. KMI answers needed to carry a mark of 4 to qualify for a *Correctness Indicator* of 1.

For the purpose of accuracy and thoroughness, the results of the recall test are tested and evaluated from five different angles. Testing **Method A** evaluates all marks from all 10 questions. Testing **Method B** evaluates the count of the *Correctness Indicators* per participant for all 10 questions. Testing **Method C** evaluates the full marks awarded only to those answers where the questions are considered to be related to the *KMI* questions. Testing **Method D** evaluates the count of the *Correctness Indicators* of the KMI questions. Testing **Method E** evaluates the count of the *Correctness Indicators* of only those answers where the questions are considered to be related to the *KB*. An evaluation of the marks for those answers has been omitted since the marks carry the same values as the *Correctness Indicators*.

6.4.2.2 Testing Method A (Sum of Marks, All)

ParticipantNumber	Mode	Marks	ParticipantNumber	Mode	Marks
1	Graphic	24	5	Tabular	8
2	Graphic	13	6	Tabular	4
3	Graphic	25	7	Tabular	4
4	Graphic	8	8	Tabular	7
12	Graphic	26	9	Tabular	3
13	Graphic	8	10	Tabular	26
14	Graphic	7	11	Tabular	6
16	Graphic	4	15	Tabular	12
19	Graphic	24	17	Tabular	2
21	Graphic	16	18	Tabular	22
24	Graphic	4	20	Tabular	24
			22	Tabular	25
			23	Tabular	13
	Sum	**159**		**Sum**	**156**
	Avg	**14.4545**		**Avg**	**12**

Table 6. 4: Testing Method A - Source Data
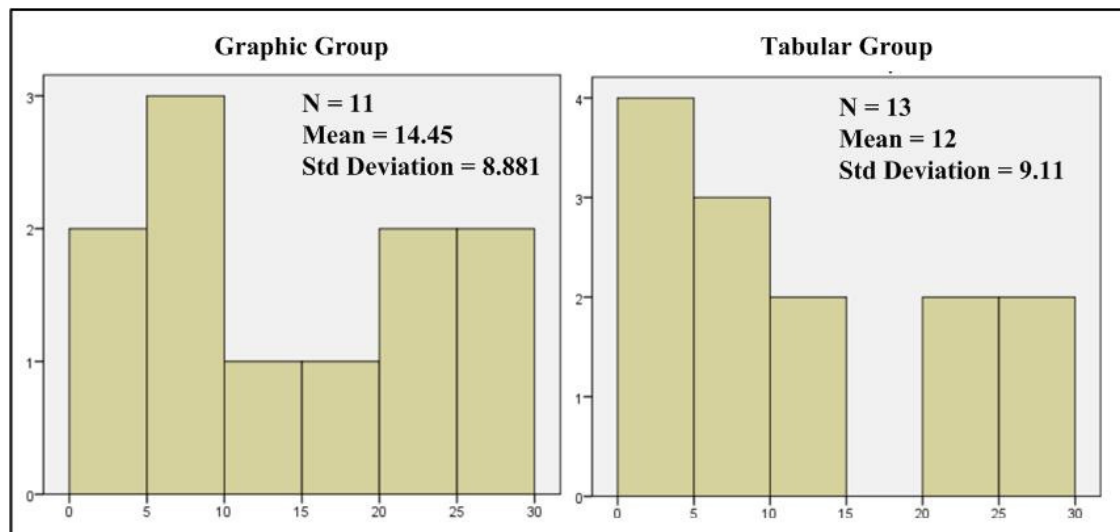
Figure 6. 12: Normality Test Histogram - Testing Method A

Shapiro-Wilk Normality Test				Mann-Whitney U Significance Test			
Group	Statistic	DF	Sig.	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Graphic	0.855	11	**0.05**	56	147	-0.902	**0.367**
Tabular	0.851	13	**0.029**				

Table 6. 5: Statistical Analysis Testing Method A

6.4.2.3 Testing Method B (Count Correctness Indicator, All)

ParticipantNumber	Mode	Task	ParticipantNumber	Mode	Task
1	Graphic	9	5	Tabular	5
2	Graphic	5	6	Tabular	4
3	Graphic	7	7	Tabular	3
4	Graphic	4	8	Tabular	4
12	Graphic	9	9	Tabular	3
13	Graphic	3	10	Tabular	8
14	Graphic	4	11	Tabular	4
16	Graphic	4	15	Tabular	5
19	Graphic	7	17	Tabular	2
21	Graphic	5	18	Tabular	7
24	Graphic	2	20	Tabular	9
			22	Tabular	7
			23	Tabular	5
	Sum	**59**		**Sum**	**66**
	Avg	**5.36364**		**Avg**	**5.07692**

Table 6. 6: Testing Method B - Source Data
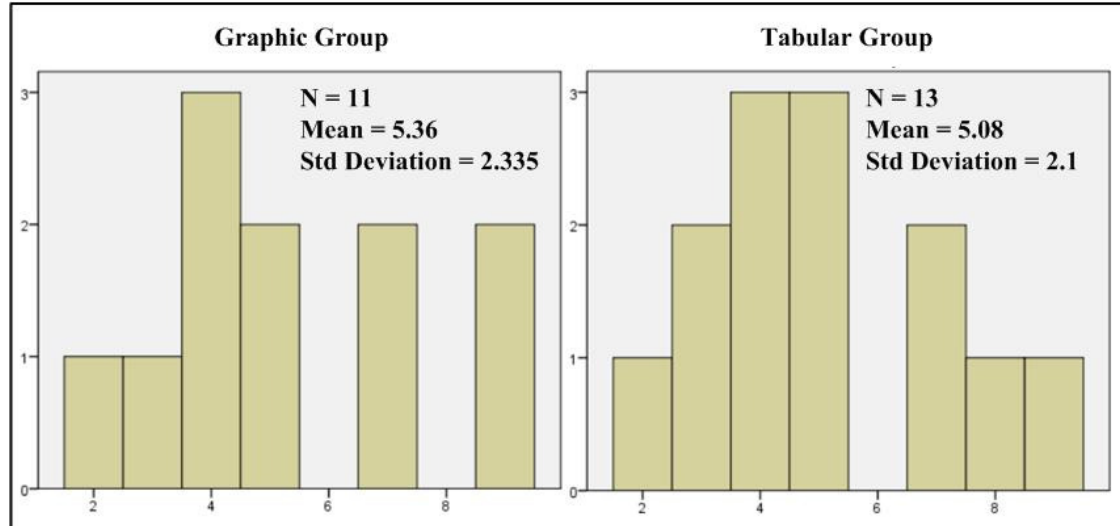
Figure 6. 13: Normality Test Histogram - Testing Method B

Shapiro-Wilk Normality Test				Mann-Whitney U Significance Test			
Group	Statistic	DF	Sig.	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Graphic	0.921	11	**0.325**	67	158	-0.265	**0.791**
Tabular	0.94	13	**0.46**				

Table 6. 7: Statistical Analysis Testing Method B

6.4.2.4 Testing Method C (Sum of Marks, KMI)

ParticipantNumber	Mode	Marks	ParticipantNumber	Mode	Marks
1	Graphic	20	5	Tabular	4
2	Graphic	9	6	Tabular	0
3	Graphic	24	7	Tabular	1
4	Graphic	4	8	Tabular	3
12	Graphic	22	9	Tabular	0
13	Graphic	5	10	Tabular	23
14	Graphic	4	11	Tabular	2
16	Graphic	0	15	Tabular	8
19	Graphic	22	17	Tabular	0
21	Graphic	14	18	Tabular	18
24	Graphic	2	20	Tabular	20
			22	Tabular	24
			23	Tabular	10
	Sum	126		Sum	113
	Avg	11.4545		Avg	8.69231

Table 6. 8: Testing Method C - Source Data
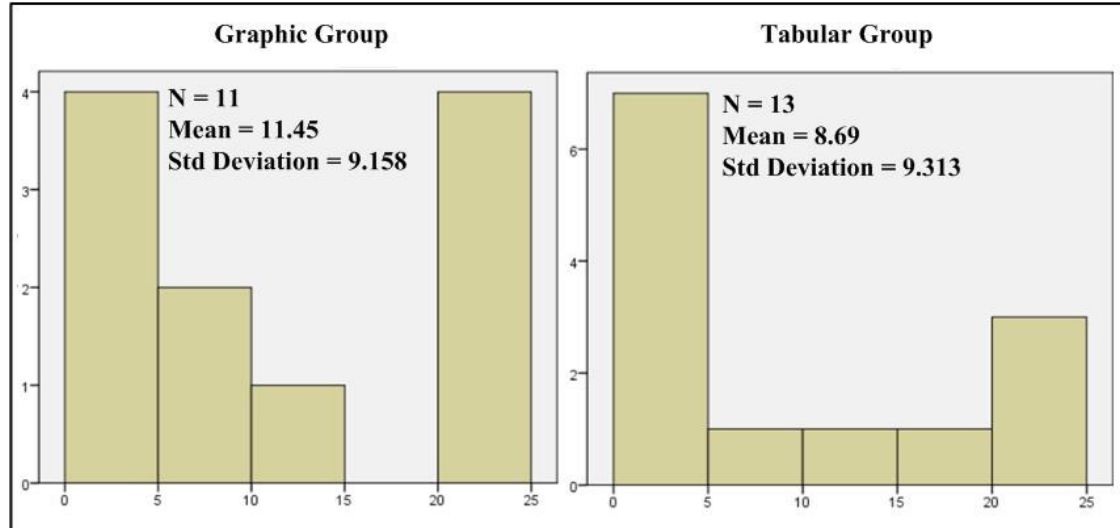
Figure 6. 14: Normality Test Histogram - Testing Method C

Shapiro-Wilk Normality Test				Mann-Whitney U Significance Test			
Group	Statistic	DF	Sig.	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Graphic	0.873	11	0.085	55	146	-960	0.337
Tabular	0.83	13	0.016				

Table 6. 9: Statistical Analysis Testing Method C

6.4.2.5 Testing Method D (Count Correctness Indicator, KMI)

ParticipantNumber	Mode	CI Count	ParticipantNumber	Mode	CI Count
1	Graphic	5	5	Tabular	1
2	Graphic	1	6	Tabular	0
3	Graphic	6	7	Tabular	0
4	Graphic	0	8	Tabular	0
12	Graphic	5	9	Tabular	0
13	Graphic	0	10	Tabular	5
14	Graphic	1	11	Tabular	0
16	Graphic	0	15	Tabular	1
19	Graphic	5	17	Tabular	0
21	Graphic	3	18	Tabular	3
24	Graphic	0	20	Tabular	5
			22	Tabular	6
			23	Tabular	2
	Sum	**26**		**Sum**	**23**
	Avg	**2.36364**		**Avg**	**1.76923**

Table 6. 10: Testing Method D - Source Data
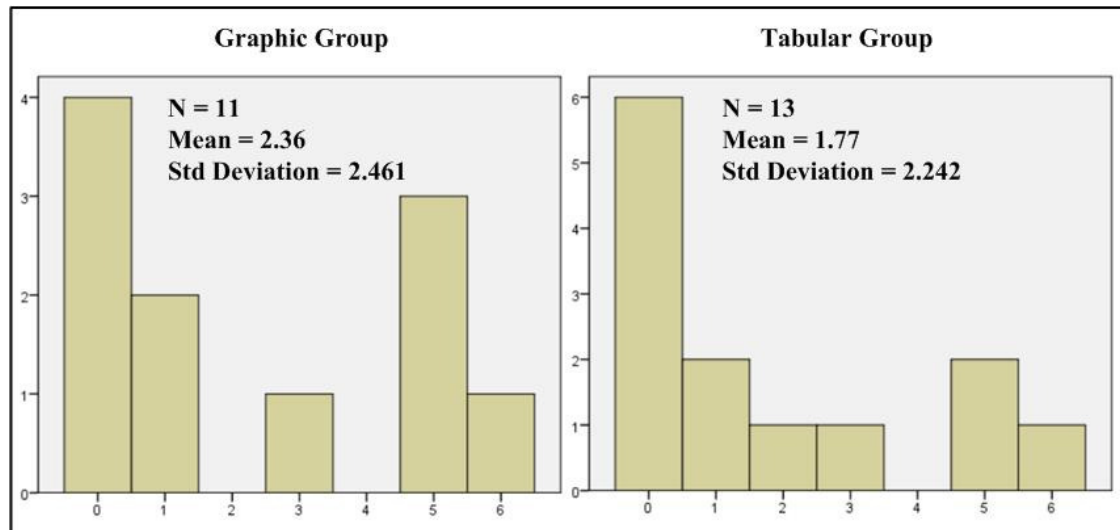
Figure 6. 15: Normality Test Histogram - Testing Method D

Shapiro-Wilk Normality Test				Mann-Whitney U Significance Test			
Group	Statistic	DF	Sig.	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Graphic	0.81	11	**0.013**	62	153	-0.576	**0.565**
Tabular	0.782	13	**0.004**				

Table 6. 11: Statistical Analysis Testing Method D

6.4.2.6 Testing Method E (Count Correctness Indicator, KB)

ParticipantNumber	Mode	CI Count	ParticipantNumber	Mode	CI Count
1	Graphic	4	5	Tabular	4
2	Graphic	4	6	Tabular	4
3	Graphic	1	7	Tabular	3
4	Graphic	4	8	Tabular	4
12	Graphic	4	9	Tabular	3
13	Graphic	3	10	Tabular	3
14	Graphic	3	11	Tabular	4
16	Graphic	4	15	Tabular	4
19	Graphic	2	17	Tabular	2
21	Graphic	2	18	Tabular	4
24	Graphic	2	20	Tabular	4
			22	Tabular	1
			23	Tabular	3
	Sum	**33**		**Sum**	**43**
	Avg	**3**		**Avg**	**3.909090909**

Given the small sample size and the minimal difference of even the arithmetic mean, no statistical analysis is warranted. H_0 is accepted.

6.4.3 Discussion of Quantitative Results

In experiments like this it is important to test if the samples may be from normally distributed populations. Due to the low sample size, the Shapiro-Wilk Test is the best option to test for normality of the samples. Testing Methods A to D show that the probability of the datasets stemming from a normally distributed population is extremely low indeed. This applies to both groups in each case. For that reason the Mann-Whitney U Test is the test of choice to test for any statistical significance of the results. The outcome for Testing Methods A to D is clear. None of the results is of any statistical significance. In fact, all results fall well short of the required 0.05 significance level. The specific data gathered through this experiment does not support the conclusion that the graphic knowledge map interface facilitates better for knowledge transfer than the tabular knowledge map interface. H_0 is accepted.

6.5 General Discussion

6.5.1 The Experiment Task

The large number of participants unable to find the answer to the Stage 4 task is surprising. Only 3 of the 11 graphic group participants and 5 of the 13 graphic group participants were successful. It may be recalled that in the trial run 5 of the 6 evaluators who reached the task stage had no problems finding the answer. The magnitude of the questions in trial run and the actual experiment was similar. It therefore would seem that the simplifications of the instructions given to the users might have been too radical. It stands to reason that a third iteration, based on the experiences of the experiment, would have eliminated this issue.

6.5.2 Identification of Component Functionality

The majority of participants had no problems identifying the relevant screen objects whose functionality was important to complete the tasks as designed. Two tabular group members did not open any knowledge base files at either the exploration or task stage. One of these participants wears corrective lenses, the other does not. The log shows that both had moved the mouse cursor over the section on the interface that holds the links to the knowledge base files.

Exloration_NumberOfFilesOpened	0	0
Task_NumOfFilesOpenend	0	0
Tabular_Explore_HoverEvent_Count	11	5
Tabular_Explore_HoverEvent_AvgDuration	0.027	0.2434
Tabular_Explore_HoverEvent_MaxDuration	0.063	0.468
Tabular_Explore_HoverEvent_MinDuration	0	0.047
Tabular_Task_HoverEvent_Count	16	5
Tabular_Task_HoverEvent_AvgDuration	0.073125	0.2962
Tabular_Task_HoverEvent_MaxDuration	0.702	0.795
Tabular_Task_HoverEvent_MinDuration	0.015	0.031

Table 6. 12: Data Analysis Log – Excerpt I

Table 6.12 makes it clear the mouse cursor movements were rather swift. The hover-event entries concerning duration are expresses in seconds. It is quite possible that they eyes of both participants were not focused on the relevant section of the screen while the events took place and therefore missed the mouse cursor changing shape and the text in the activated boxes turning bold.

It is of great concern, however, that 5 of the 11 graphic group participants did not access any knowledge base files.

Graphic_Explore_L1_HoverEvent_Count	11	5	17	1	4
Graphic_Explore_L1_HoverEvent_AvgDuration	0.268363636	0.3624	7.146	51.547	2.3905
Graphic_Explore_L1_HoverEvent_MaxDuration	1.015	0.484	100.531	51.547	9.391
Graphic_Explore_L1_HoverEvent_MinDuration	0	0.016	0.062	51.547	0.031
Graphic_Expore_L2_HoverEvent_Count	0	0	0	0	0
Graphic_Expore_L2_HoverEvent_AvgDuration	0	0	0	0	0
Graphic_Expore_L2_HoverEvent_MaxDuration	0	0	0	0	0
Graphic_Expore_L2_HoverEvent_MinDuration	0	0	0	0	0
Graphic_Task_L1_HoverEvent_Count	6	11	11	2	9
Graphic_Task_L1_HoverEvent_AvgDuration	0.028666667	0.318181818	0.578090909	0.0465	0.599444444
Graphic_Task_L1_HoverEvent_MaxDuration	0.047	2.375	4.297	0.078	4.258
Graphic_Task_L1_HoverEvent_MinDuration	0	0.016	0	0.015	0
Graphic_Task_L2_HoverEvent_Count	0	0	0	0	0
Graphic_Task_L2_HoverEvent_AvgDuration	0	0	0	0	0
Graphic_Task_L2_HoverEvent_MaxDuration	0	0	0	0	0
Graphic_Task_L2_HoverEvent_MinDuration	0	0	0	0	0

Table 6. 13: Data Analysis Log - Excerpt II

Table 6.13 shows that none of the participants clicked on any of the four Level 1 quadrants to view the concept map on Level 2. One participant had the mouse cursor placed on one of the four quadrants for over 51 seconds. Several of the participants concerned responded to follow-up mails that were sent out to seek clarification. The result was indeed that they had not realised that the four quadrants were interactive. At this point it is instructive to recall that a quadrant changes colour, the image in it grows and the mouse cursor changes shape when a hover-over event occurs. Analysing the statistical data provided by the participants in question shows a reasonable spread, only three variables that form a kind of pattern. *Table 6.14* provides the details. The relevant variables are highlighted.

AgeGroup	21 - 30	41 - 50	41 - 50	31 - 40	31 - 40
Gender	Female	Female	Female	Male	Female
CorrectiveLenses	No	Yes	Yes	Yes	Yes
LeftHanded	No	No	No	Yes	No
LifeActivity	Dealing with Data or Numbers	Dealing with People	Leading/Motivating People	Teaching People	Dealing with Data or Numbers
FirstLanguage	Irish	Italian	German	English	German
UseOfEnglish	Exclusively	Mostly	Practically never	Exclusively	Mostly
UseOfComputers	Constantly at work and at home	At home constantly	At home constantly	Constantly at work and at home	At work constantly
PreferedLearningMaterial	A Combination of Both	A Combination of Both	A Combination of Both	A Combination of Both	Visual Material
SauerkrautMakingFamiliarity	Somewhat familiar with it	Never heard of it	Very familiar with it	Somewhat familiar with it	Somewhat familiar with it

Table 6. 14: Data Analysis Log - Excerpt III

At this point, the small sample size must be taken into account. The probability of this circumstance being pure coincidence is considerable. However, it would appear to be warranted to suggest further investigation into this issue. It would be particularly interesting to examine whether or not the wearing of corrective lenses could potentially have such an impact on the perception of the user, and if so under what circumstances.

6.5.3 Investigating Extreme Results (Recall Test)

This section compares two pairs of extreme results, one from each participant group, with the aim to seek explanations for the very different results. The full data analysis logs of the four participants can be examined in Appendix D.

6.5.3.1 P09 versus P10 (Tabular Group)

Participant number 9 (P09) produced one of the lowest results in the recall test while participant number 10 (P10) produced the highest result of all graphic group participants. An examination of the data listed in *Table 6.15* reveals that, apart from the gender, there are no major factors setting these two participants apart. P9, in fact, could be anticipated to fare better since one would expect his more frequent use of the English language to be an advantage. This, however, was clearly not the case. Motivation also appears to have not played a role. P09 was successful in the

experiment task while P10 was not. P09 spent 14 minutes on the experiment. P10 spent 19 minutes on the experiment. [It may be noted at this stage that the field 'ProjectDuration' features time expressed in milliseconds.] It is doubtful that the 5 minutes difference can account for the outcomes. Both are also very familiar with the making of sauerkraut. There seems to be no explanation for the discrepancy.

ParticipantNumber	9	10
Mode	Tabular	Tabular
AgeGroup	31 - 40	41 - 50
Gender	Male	Female
CorrectiveLenses	No	No
LeftHanded	No	No
LifeActivity	Handling Technology (Other)	Handling Technology (Other)
FirstLanguage	German	German
UseOfEnglish	In social interactions mostly	Practically never
UseOfComputers	Constantly at work and at home	Constantly at work and at home
PreferedLearningMaterial	A Combination of Both	A Combination of Both
SauerkrautMakingFamiliarity	Very familiar with it	Very familiar with it
ProjectDuration	898796	1125641
TaskResponse	cloth	sauerkraut
TaskStatus	Correct	Incorrect
A_AllMarks	3	26
B_KMIMarks	0	23
A_Count_CorrectnessIndicator	3	8
B_Count_CorrectnessIndicator	0	5

Table 6. 15: Comparing P09 and P10

A follow-up revealed that P10 several years ago had received very specific human resources related memory training. That training aimed to enable the individual to quickly memorise data items from a document that are unfamiliar while blocking out or ignoring sections of the same document that deal with data items the individual already is familiar with.

This finding is rather important. Existing skills and the potential positive impact of such skills is of great importance in KM. Suitable ways must be found to include this variable into future research.

6.5.3.2   P12 versus P24 (Graphic Group)

The comparison between participant number 12 (P12) and participant number 24 (P24) also makes for an interesting comparison. P12 achieved the highest score of all graphic group participants, while P24 achieved one of the lowest scores. P12 and P24 stated a preference for visual learning material. Neither was successful in the experiment task. One might expect P24 to have a slight advantage, due to some familiarity with the making of sauerkraut. However, that was not the case. One potential issue here could be the question of motivation. P 12 spent 13 minutes on the project while P24 only expended 6 minutes on the experiment. P24, as the full data analysis log reveals, spent only 59 seconds at the exploration stage and 53 seconds at the task stage, and never accessed any of the knowledge base files. While the top layer or the graphical interface is sufficient to promote a high score, it stands to reason that such short exposure was insufficient to lead to any serious recall. Another potentially interesting fact is that, while P24 stated to prefer visual learning material, she works mostly with data and numbers. Individuals with such a background may have gotten used to information being presented in tabular format.

ParticipantNumber	12	24
Mode	Graphic	Graphic
AgeGroup	21 - 30	31 - 40
Gender	Male	Female
CorrectiveLenses	No	Yes
LeftHanded	No	No
LifeActivity	Handling Technology (Computing)	Dealing with Data or Numbers
FirstLanguage	English	German
UseOfEnglish	Exclusively	Mostly
UseOfComputers	At work constantly	At work constantly
PreferedLearningMaterial	Visual Material	Visual Material
SauerkrautMakingFamiliarity	Never heard of it	Somewhat familiar with it
ProjectDuration	788359	356883
TaskResponse	cutting machine	cabbage
TaskStatus	Incorrect	Incorrect
A_AllMarks	26	4
B_KMIMarks	22	2
A_Count_CorrectnessIndicator	9	2
B_Count_CorrectnessIndicator	5	0

Table 6. 16: Comparing P12 and P24

6.5.4 Technical Issues Highlighted

The issue many participants experienced with the ZIP file may indicate that is any endeavour as was simulated with this experiment; it is vital for the designer that the user may not be technical. It is unlikely that the ZIP file approach be taken again, however, this lesson can well be generalised to point to any activity that requires or assumes a certain level of technical knowledge on part of the user.

The general issue of interoperability has also been highlighted by the exclusion of users of other operating systems than Windows. For such and experiment or actual implementation tool it is indispensable that it be accessible to all users.

6.6 Conclusions

This chapter presented and discussed issues arising from the experiment and its results. The experiment failed to provide evidence that a graphical knowledge map interface facilitates better results in knowledge transfer. This null finding may or may not be due to the small sample size. However, it succeeded in highlighting potential technical issues that might arise on implementation of a KM that it simulated. It also succeeded in identifying at least one variable that is particularly important as far as KM and OKC related research is concerned.

7 CONCLUSIONS AND FUTURE WORK

7.1 *Conclusions*

7.1.1 Computing for Knowledge Management

The literature review opened its deliberations by providing a clear explanation of two key concepts this dissertation is concerned with, OKC and KM. OKC is a theory from the field of the organisational sciences. KM on the other hand is a practical implementation of OKC. They relate to one another like a class to an instance of the class in object-orientated programming. The literature review also suggests that the confusion surrounding the whole field of KM is primarily due to cultural misunderstandings. OKC is deeply routed in Asian culture (Nonaka, 1994). The implication of this is that any attempt to implement such a philosophy applying typical Western attitudes, approaches and structures is bound to lead to precisely the kind of confusion that can be witnessed today. Another factor is that, the literature and research in the field of KM displays a strong focus on very specific initiatives that generally seek to implement selected segments of OKC. This only adds to the confusion since every initiative is profoundly different. Irrespective of the value and quality of project and published case study, more often than not there is very little that can be generalised from these findings. It is impossible to identify all the relevant variables that account for the outcome of the specific project. Cause and effect can hardly ever be clearly identified and separated. In order to solve this problem, it is suggested that a clear distinction must be made between the theory of OKC and its practical implementations which have come to be known under the almost umbrella term Knowledge Management. The latter, due to its philosophical nature, does not lend itself easily to scientific research. OKC on the other hand is a well-defined organisational theory and therefore has the potential to produce scientific results if subjected to focused research. Seeing the current situation of KM, it does not come as a surprise that the field of Computing for KM finds itself in the same place. An examination of several technologies that frequently are marketed as KM tools

demonstrates that current technology is not truly implementing OKC. KM technologists wishing to establish Computing for KM must create that position themselves. Drawing from the field of organisational strategy, it is found that KM technologists must find and concentrate on a specific niche. The most important focus area of OKC is the transfer of knowledge throughout an organisation. It therefore appears to be sensible that KM technologists concentrate on knowledge transfer as a research area. Creating a core competency in this area has the potential to create a strategically unique position for computing. One might even go so far as to aim at establishing such a strategic position for Computing for OKC rather than KM. A goal such as this cannot be achieved by drawing on one field of science alone. One must seek inspiration from the computer sciences, cognitive psychology and the social sciences.

7.1.2 Visualisation

One must keep in mind that OKC itself is an organisational theory that aims to create a knowledge society that is truly humanistic and goes beyond "*mere economic rationality*" (Nonaka, 1994). It does not at all deal with technological issues. Computing for KM that has an OKC focus truly enters the stage when it is called on to substitute for personal face-to-face interaction. The field of visualisation for decades has independently researched precisely the issues that arise in such situations. It also is concerned with the transfer of meaning and knowledge. In terms of computing, Visualisation can be considered a sub-set of Human-Computer Interaction. The latter is rooted in precisely those disciplines this dissertation proposes to KM technologist as sources for inspiration. Visualisation and OKC therefore may be considered the perfect match. Its subset of knowledge visualisation in particular researches issues like ambiguity and how to best help the cognitive processes of the user.

7.1.3 Knowledge Maps

Knowledge maps are a subset of knowledge visualisation and therefore inherit all its benefits. They display previously captured information and its relationships (Vail,

1999) and have an exceedingly strong focus on the transfer of knowledge. As such the field is the perfect candidate for KM implementations that focus on OKC. Concept maps, probably one of the most important implementation of knowledge maps, in terms of OKC and KM, are particularly well positioned to keep the *SPIRAL* going. A concept map is never finished; it needs to be revised constantly (Novak and Cañas, 2008). This helps to create shared meaning in an organisation (Eppler, 2001; Burkhard and Meier, 2005), shape the environment in favour of the information forager as described by Pirolli and Card (1999) and promote the sharing of tacit knowledge (Houari and Far, 2004). All these qualities make knowledge maps the ideal candidate for the experiment that was conducted as part of this dissertation.

7.1.4 Experimental Process

The experiment was designed to find hints and answers to very basic issues that would arise in a real life situation.

❑ Do a different knowledge base interface lead to a difference in the recall ability of the participants?

❑ Will the individual users recognise the interactivity of components and use them?

❑ Are there any known or unknown variables that must be taken into account when embarking on such an endeavour?

❑ What are the potential issues that might arise in cases where a similar knowledge map front end is being implemented?

In order to achieve these goals, the design had to have very specific recording and file creation capabilities. The only feasible solution to such a challenge will always be a compiled binary or executable file. The solution was a considered trade-off between reaching participants and gathering the right kind of data. Hard coding the content of the experiment was never an option. This produced a software project implementation consisting of 77 individual files. The only option to distribute such a project will

always be a ZIP file. That ZIP file then was published on a website and participants were sought through emails.

The experiment succeeded in three of the four objectives. The data does not support the hypothesis that a graphical interface compared to a tabular interface leads to better recall ability of the participants. However, one variable very important to OKC and KM was identified, types of technical issues that might arise during the implementation of such a KM too were highlighted, and an issue with functionality recognition was earmarked for further research.

7.1.5 Lessons Learned

The above discussions, and the experiment along with its analysis and evaluation teach the following lessons.

1. **Release an Initial Prototype ASAP**: Another very important lesson that can be learned for the experiment is the issue of timing. Early July is not a good time of year to set out on such an endeavour. Many more people, particularly students and lecturers, may have participated had they been in their offices or at home.

2. **Visual Representations Necessitate Iteration**: The experiment tool in an ideal world would have gone through another development iteration. Another iteration might make all the difference now that we know the weaknesses. Considering the setup of Irish masters dissertations and the short time-span available it was impossible to do so.

3. **Keep it Simple**: Dillon et al. (2005) observe that, a lightweight and easy to use interface is by far more important than all possible advanced features that can be conceived. The experience with the experiment prototype has confirmed this observation. There is no point including features that distract from the content. The channel must not interfere with the message.

4. **Never Assume an Equivalent Technical Vocabulary in Your Audience**: Many participants had serious problems with the handling of the ZIP file. This shows clearly that the design and the implementation should not exclusively be left to the technically inclined. A non-technical individual may have pointed out that the distribution website in such a case must contain simple instructions on how to deal with such a file.

5. **People have Different Preferences in terms of Interfaces**: The cognitive sciences and the research field of learning styles make it clear that not everything works for every one. Ideally people should have the option to set the interface to their liking.

6. **People use Different Types of Computers**: Only Windows users were able to participate in the experiment. Mac and Linux users for instance were excluded by design. This was unavoidable given the short period of time available to conduct the experiment. This is clearly not satisfactory and must be addressed in further experimentation.

7. **Visualisation is a Multifaceted Research Area**: Visualisation is a rich area of research with many facets to it and deep widespread roots. This dissertation could barely scratch the surface.

7.2 Future Work

The future work discussed in this section is not limited to experimentation. Many issues treated as open here, may already have been researched and to a degree solved. A further and even deeper literature review into every single area addressed by this dissertation is recommended before embarking on additional experimentation. Any further research should share the spirit of *Information Foraging Theory* (Pirolli and Card, 1999). ACT-IF strives to help understand how people shape themselves to the environment and how the environment can be shaped to suit people, and so should all those that endeavour this kind of research.

7.2.1 Computing for Knowledge Management

The experience with the experiment prototype makes a showcase of how important the interaction and relationship between mapmakers and users (Wexler, 2001) really is. The expert creates the structure of the knowledge (Trumpower and Goldsmith, 2004) and the mapmaker implements it. But all that is to be done for the benefit of the user. Constant interaction between all parties involved keeps the *SPIRAL* turning. These interactions, however, cannot be completely unstructured. OKC does not call for total anarchy. Management cannot entirely let go of the reigns completely (Nonaka, 1994). Suitable and flexible processes must be put in place allowing the organisation and the individual to thrive. For that reason research should be conducted into methodologies specifically catering for the development and maintenance of KM tools like knowledge maps fronting knowledge bases. In such research it will be vital to never lose sight of the ultimate goal. The *SPIRAL* must be turned on and kept going. Agile methodologies seem a good option as a starting point for this kind of research.

7.2.2 Visualisation

Scientists researching visualisation generally do so independently from the field of KM. More research that looks at visualisation through a focused OKC lens would be desirable.

Identifying the key researchers in the field of visualisation in KM is a key step to understanding where the field is going. For this research, they have been identified as Martin J. Eppler, Remo A. Burkhard and the group around them.

7.2.3 Knowledge Maps

In terms of further research conducted into knowledge maps, it will be most important to gather knowledge specific quantitative data.

- What works for the user?
- What features are really needed?

❑   How can knowledge maps be tied into larger systems for which they may be used as front-end tools?

7.2.4 Experimental Process

More basic research is needed to identify common variables. What are they? Can they be defined and categorised?

As for the experiment of this dissertation, it stands to reason, that the experiment in a slightly more developed form should be repeated under controlled conditions. Many otherwise undetectable variables like distraction can be eliminated and participants can be interviewed about their experience there and then. Third level institutions may be a good place to do so. The dissertation experiment raised the issue of timing; it therefore would seem to be best to do so at a stage early in the semester, not in and around exam time.

Further research might also be conducted into finding out why people may not perceive the full functionality of specific features. This might enable knowledge map designers to include profiling features where, based on answers to certain questions a user is presented with specific hints and advice while using the knowledge map.

The issue of why such a great portion or graphic group participants did not recognise the interactivity of the Level 1 quadrants needs to be investigated further.

7.2.5 Lessons Learned

The experiences from this research project and the lessons learned allow for the following advice to be passed on.

1. **Release an Initial Prototype ASAP**: Releasing a prototype will help to understand the users' goals and motivations; this is vital and will strongly influence the further development since people generally do not think like computers or even designers (Cooper et al., 2007, p. 4 - 10).

2. **Visual Representations Necessitate Iteration**: Make sure the tool is designed in such a fashion that it can be modified swiftly and easily. The prototype of the experiment described in this dissertation was turned into the final tool within one single day. Always avoid hard coding and insert appropriate comments into the code.

3. **Keep it Simple**: Do not overload the users' cognitive systems with features that distract from the purpose of the endeavour. Any effort expended on figuring out the functionality of the tool or battling confusion will have been expended without any benefit to the purpose the tool serves. Keep the number of screen object to the absolute minimum. Keep any instructions displayed as brief as possible without compromising the message.

4. **Never Assume an Equivalent Technical Vocabulary in Your Audience**: It is vital to prototype the entire user experience (Cooper *et al.*, 2007, p. 142). Using this approach will prevent many detrimental issues from materialising.

5. **People have Different Preferences in terms of Interfaces**: Make sure to gain a reasonable level of understanding of for instance the fields of cognitive psychology and HCI. Keep the principles of Universal Design firmly in mind, do so from the very beginning of the development. Consider the possibility of profiling where features may be included, which based on certain input given by the user (e.g. answers to statistical questions) s/he is presented with specific hints and advice while using the knowledge map.

6. **People use Different Types of Computers**: Make sure that your tool runs smoothly on all types of computers and operating systems.

7. **Visualisation is a Multifaceted Research Area**: Be certain to measure the experiment in as many ways as possible. Ensure that the data collection process (which may include questionnaires, interviews, participant observations, button and mouse tracking, etc.) will probe for the classical sources of bias in Cognitive Psychology, Interface Design, HCI, etc.

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APPENDIX A: KNOWLEDGE BASE CONTENT

The content of the knowledge base as presented in the experiment is divided into four different areas of expertise.

- ❑ Growing Cabbage
- ❑ Cutting Cabbage
- ❑ Seasoning Cabbage
- ❑ Curing Sauerkraut

Field of Expertise: Growing Cabbage

The Right Cabbage

needs   is harvested

Rain   Summer
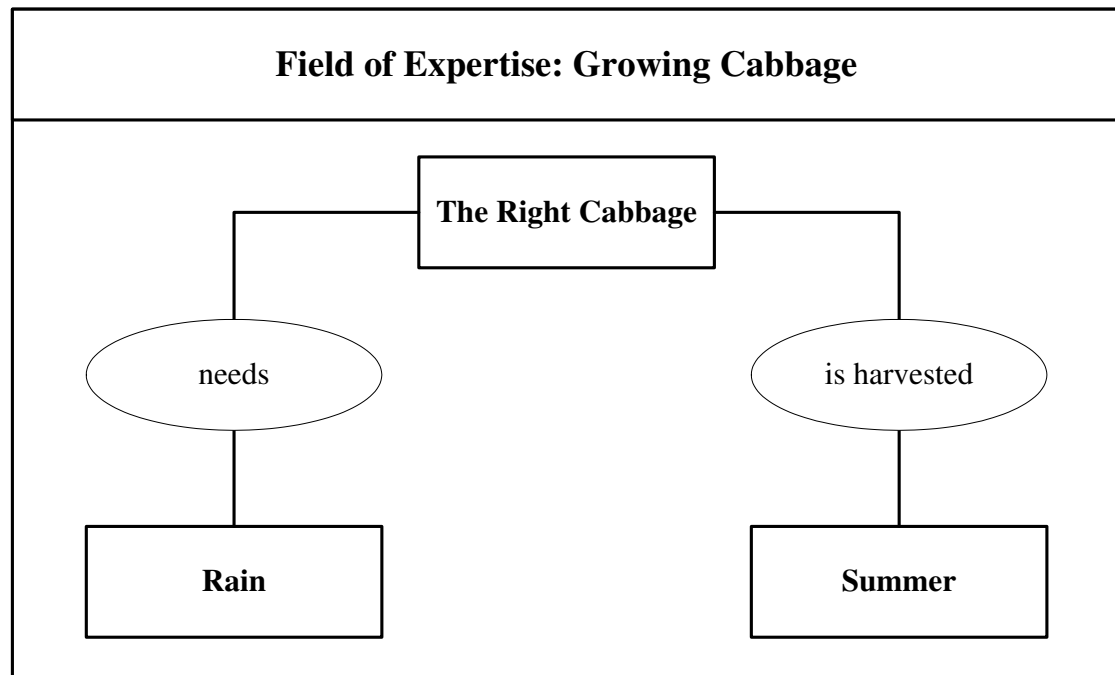
Content of … The Right Cabbage

GOOD CABBAGE - CONCEPT

Sauerkraut obviously is made from cabbage. However, not just any cabbage will do. One needs the right type of cabbage that was grown and harvested at the right time.

Content of … needs

GROWING CABBAGE - RELATIONSHIP

Growing the right cabbage needs the right amount of rain.

Content of … Rain

GOOD CABBAGE - CONCEPT

RAIN

Like most vegetables, cabbage depends on just about the right amount of rain. Too little and the cabbage will be too dry. Too much rain and the cabbage turns too coarse. Plus it will be prone to spoil.

At this point we may want to remember that true sauerkraut only knows one preservative and that is salt.

Content of … is harvested

GROWING CABBAGE - RELATIONSHIP

The right cabbage is harvested in summer.

Content of … Summer

GOOD CABBAGE - CONCEPT

SUMMER

Summer cabbage is just right for sauerkraut. The texture is perfect and the content of juice makes for the perfect outcome.

Spring cabbage is far too mushy. One will end up with a cabbage mash rather than sauerkraut. While this might be fine for those of us who have misplaced their dentures, it is not really desirable.

Autumn cabbage is too dry and stringy. Unlike one enjoys chewing on something resembling damp straw it should be avoided.

Field of Expertise: Cutting Cabbage

```
                    ┌─────────────────┐
                    │  Manual Cutting │
                    └─────────────────┘
              ┌───────────┘         └───────────┐
        ╭─────────────╮                   ╭─────────────╮
        │ right amount │                   │   demands   │
        │     of       │                   ╰─────────────╯
        ╰─────────────╯                          │
              │                                   │
        ┌──────────┐                        ┌──────────┐
        │ Pressure │                        │  Rhythm  │
        └──────────┘                        └──────────┘
```
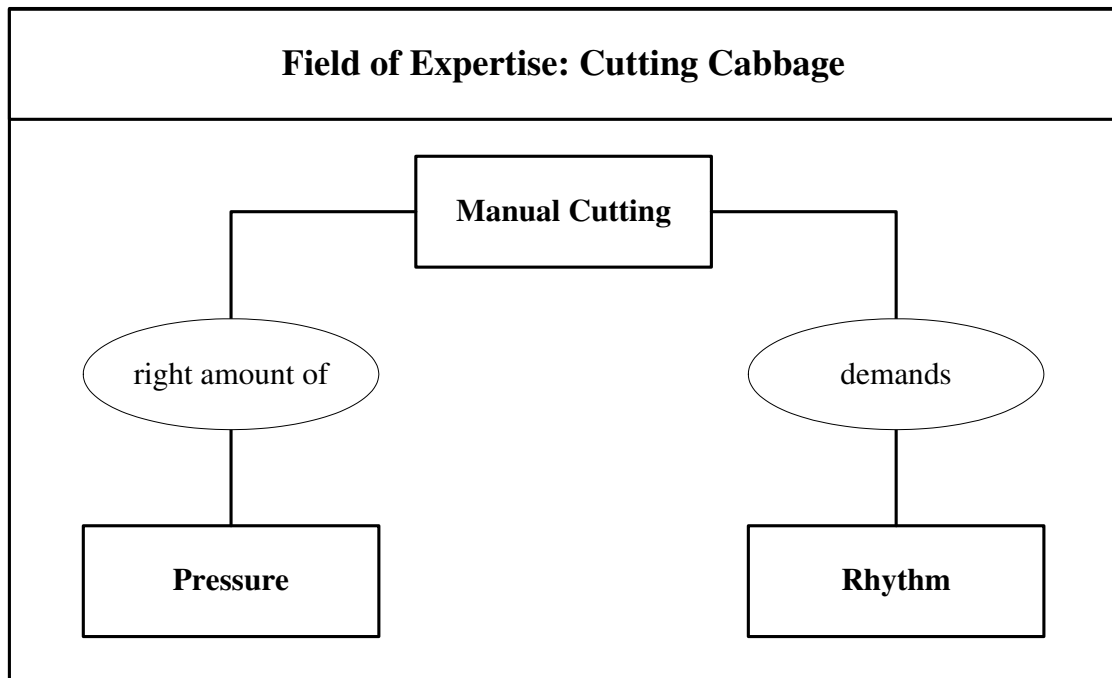
Content of … Manual Cutting

MANUAL CUTTING - CONCEPT

Sauerkraut obviously is not cut or chopped with a knife. The tool used is a Krauthobel, which can be described as a kind of inverted carpenter's plane. It is the shavings that will become delicious sauerkraut one fine day.

The artist knows not to use the outermost layers, the stalk and any dodgy leafs. Try to explain that to a machine.

Content of … right amount of

MANUAL CUTTING - RELATIONSHIP

The manual cutting of the cabbage needs the right amount of pressure.

Content of … Pressure

MANUAL CUTTING - CONCEPT

PRESSURE

The cabbage shavings that make up the sauerkraut must be of the same thickness throughout an individual batch.

The consistency of the cabbage will vary from harvest to harvest and sometimes even from farmer to farmer. The true artist will adjust the pressure applied during the cutting or shaving accordingly.

The divine will manage to get the same result every year.

Content of … demands

MANUAL CUTTING - RELATIONSHIP

The manual cutting of the cabbage demands a steady rhythm.

Content of … Rhythm

MANUAL CUTTING - CONCEPT

RHYTHM

Passing the cabbage head over the blades must be done using a good and steady rhythm. Otherwise one will get stuck. And that leads to clusters of connected shavings. Machines do that at times.

If you have ever stuck a fork into sauerkraut and found yourself lifting half the plate, well, that's what happened.

Field of Expertise: Seasoning Cabbage

```
                        ┌──────────────┐
                        │  Seasoning   │
              ┌─────────┴──────────────┴─────────┐
      ╭───────────────╮                  ╭───────────────╮
      │ requires little │                  │   is done by    │
      ╰───────┬───────╯                  ╰───────┬───────╯
      ┌───────┴───────┐                  ┌───────┴───────┐
      │     Salt      │                  │    Layers     │
      └───────────────┘                  └───────────────┘
```
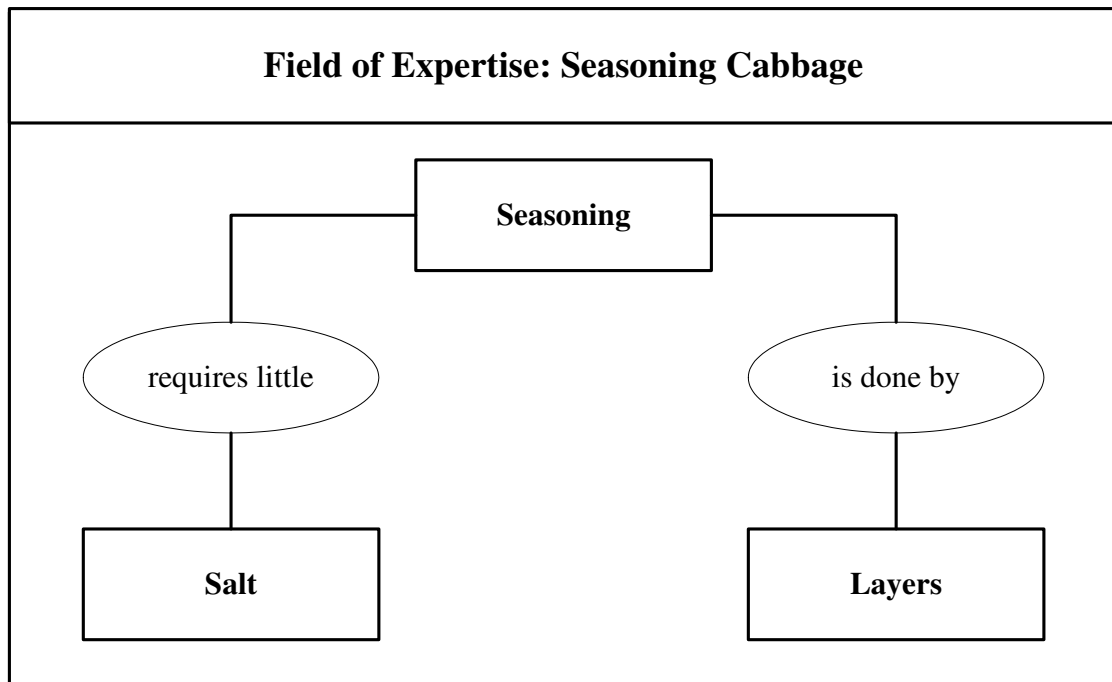
Content of … Seasoning

SEASONING – CONCEPT

Seasoning is very important in the making of Sauerkraut. Contrary to popular belief only three items are added to the cabbage.

Salt, juniper berries and cumin seeds. And that is it. If one finds anything else, that is not sauerkraut.

Content of … requires little

SEASONING - RELATIONSHIP

The seasoning of the cabbage requires very little salt.

Content of … Salt

SEASONING - CONCEPT

SALT

Sauerkraut is not about salt. In fact, one can tell the abomination from the real thing by its salt content. As for some of the industrial atrocities, well, one might just as well slurp congealed acid.

The true artist manages to make a 50-litre barrel of sauerkraut with only 750 grams of salt. The divine manage with half a kilo, but those are few and far between.

Content of … is done by

SEASONING - RELATIONSHIP

The seasoning of the cabbage is done by layers.

Content of … Layers

SEASONING - CONCEPT

LAYERS

One does not make a 50-litre barrel of sauerkraut and adds the seasoning all at once. Oh no, one cuts a sub-batch, adds the seasoning, mixes it all thoroughly and puts the mix in the barrel.

After that the mix is squashed with a wooden implement. One might call it stomping. Stomping must be considered a part of the seasoning even though it is a manual process. It is a process that requires brute force and sensitive feel. Good luck trying to set up a machine to do that.

A good layer, once stomped is no thicker than about 10 centre metres. The better the artist with the stomping, the less seasoning is required. Less seasoning means milder sauerkraut. Machines can only dream of achieving that.

Field of Expertise: Curing Sauerkraut

Curing

takes

calls for

Time

Environment
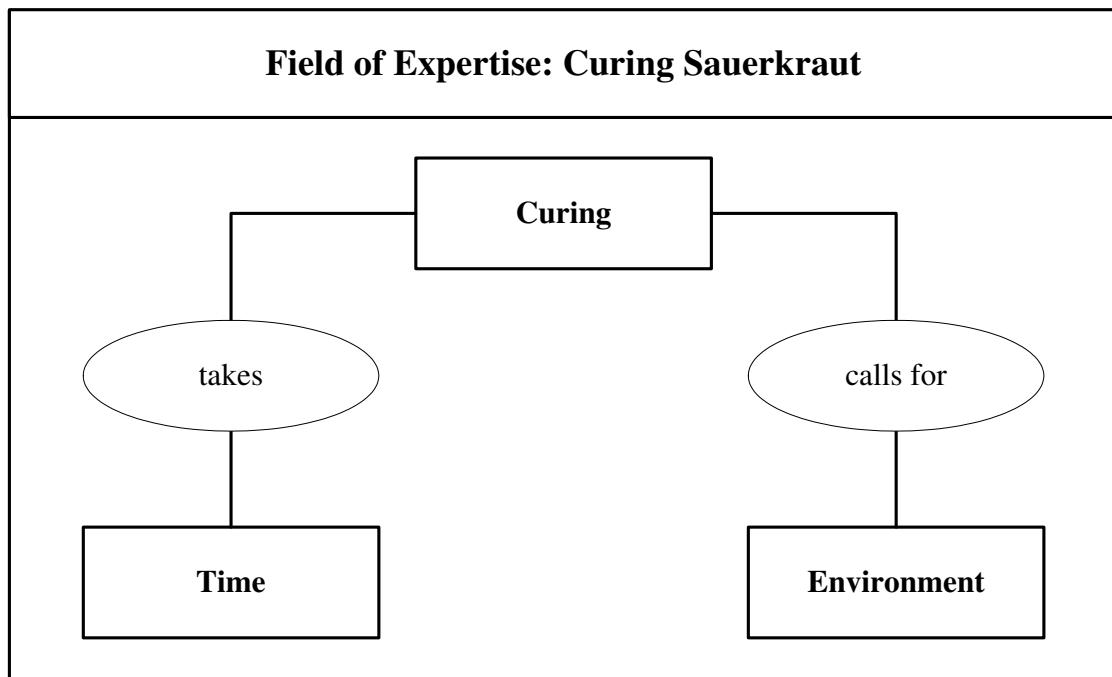
Content of … Curing

CURING - CONCEPT

Sauerkraut is not made and then cooked right away. The seasoned and squashed cabbage shavings need to cure or ferment first. The curing process starts when the mix in the barrel is covered with a linen cloth, never use anything but linen, closed off with wood and weighted down with a stone.

Great attention must be paid to the barrel during that time. This involves a great deal of care work. The barrel must be watched all the time.

The cloth needs to be replaced regularly.

The wood lid and the stone must be washed thoroughly and carefully each time the linen is replaced.

Content of … takes

CURING - RELATIONSHIP

The curing of sauerkraut takes time.

Content of … Time

CURING - CONCEPT

TIME

Oh yes, it takes time for the mix to turn into sauerkraut. One can expect to care for the barrel for six to eight weeks before the sauerkraut can be enjoyed.

Making first-class sauerkraut for profit, well, that is not likely to happen.

Of course one can speed up that process. Just add loads and loads of salt. This pretty much explains the industrial abominations that are sold as sauerkraut.

Content of … calls for

CURING - RELATIONSHIP

The curing of sauerkraut calls for a special environment.

Content of … Environment

CURING - CONCEPT

ENVIRONMENT

One cannot place a barrel of curing sauerkraut just anywhere. The right conditions are required.

A dark cool place is ideal. Something like an old-fashioned cellar with stonewalls and a stone floor will work best.

It must not be too humid, otherwise mold or rot will spoil the precious sauerkraut.

APPENDIX B: EXPERIMENT DISTRIBUTION
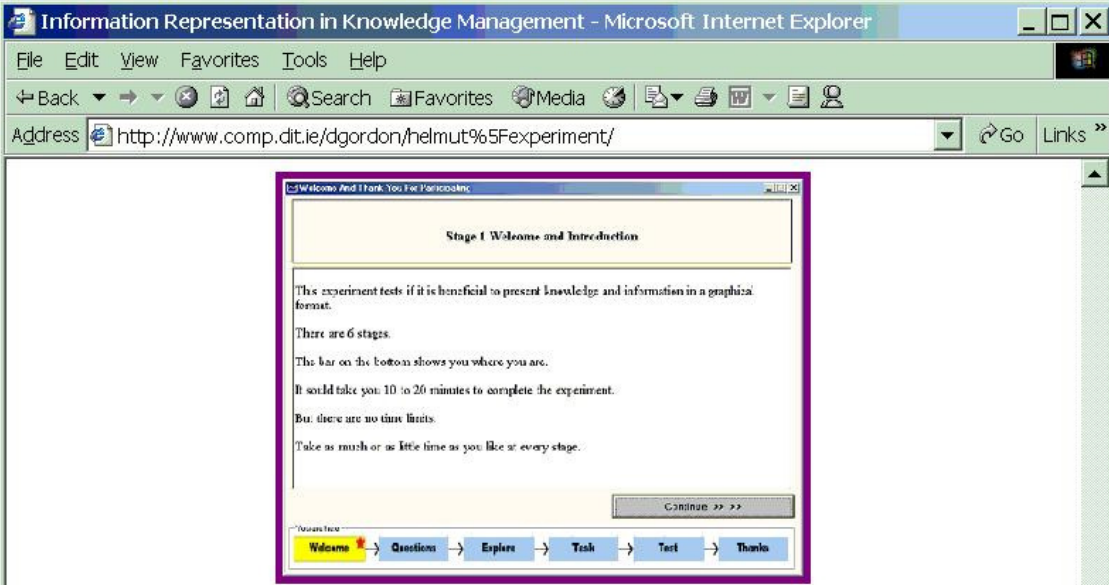
This appendix illustrates the execution of the distribution design and approach. It features screenshots of the website used for distribution, the ReadMe file and the content of two example 'Request for Participation' emails.

AB-1: Website Part I
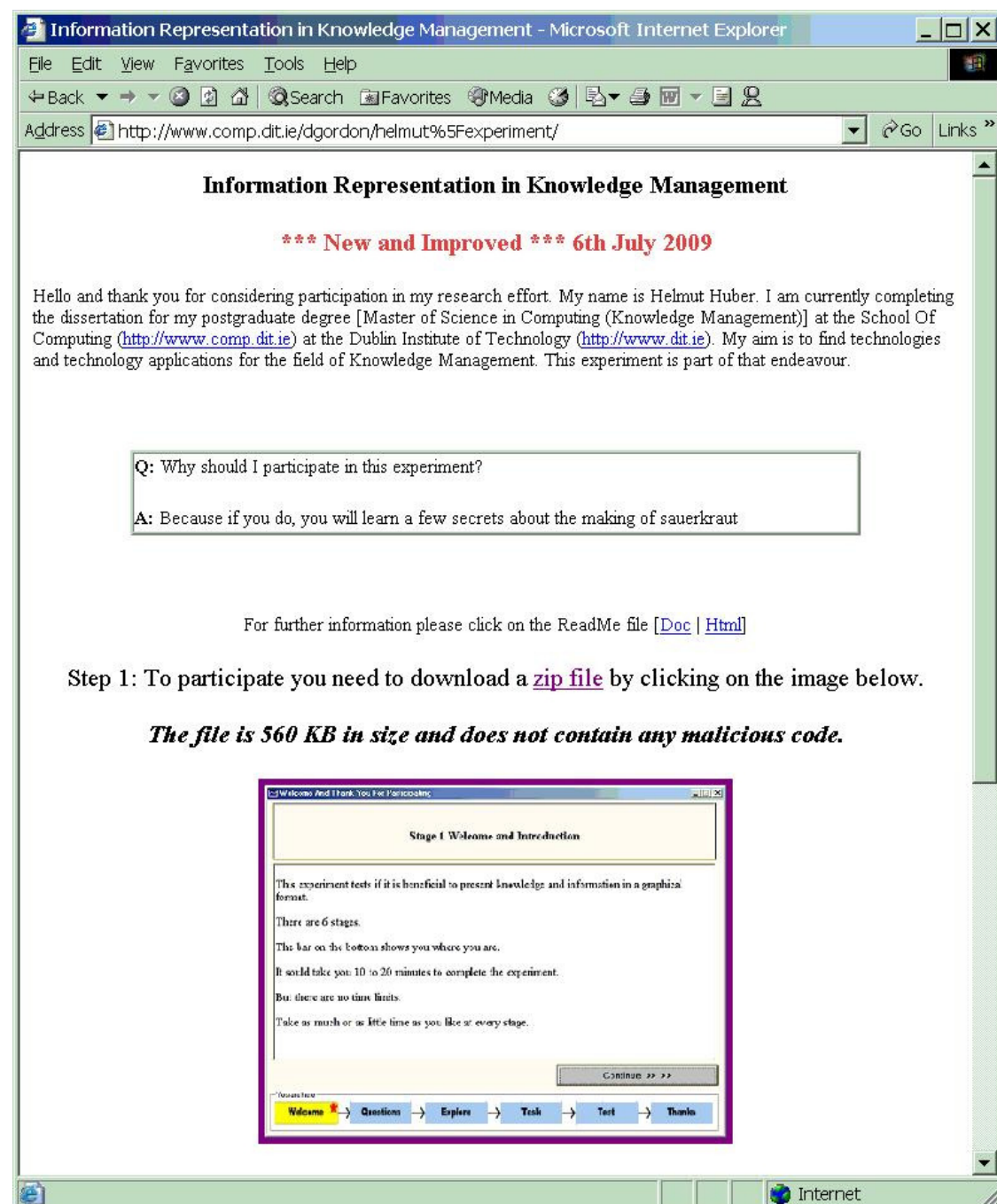
Hello and thank you for participating in my research effort. My name is Helmut Huber; I am currently completing the dissertation for my postgraduate degree [Master of Science in Computing (Knowledge Management)] at the School Of Computing (www.comp.dit.ie) at the Dublin Institute of Technology (www.dit.ie).

My aim is to find technologies and technology applications for the field of Knowledge Management.

This experiment is part of that endeavour. This document gives you an overview and a few explanations.

System Requirements:

❑   Any of the Windows family operating systems.

The completion will take about 10 to 20 minutes. There are, however, no time limits in either direction.

The Experiment

This experiment is designed to test if it is truly beneficial to present knowledge and information in a graphical format. There are 6 stages.

You will be asked to familiarise yourself with some information, find a particular piece and recall some details. For that purpose you will be confronted with either a graphical interface or an interface resembling a spreadsheet.

As for this tool or application:

- This application does not need to be installed.
- This application does not contain any malicious content or code.

- It only tracks your activities within its boundaries and notes your answers to the questions and the results of some tasks.
- It will write a file to the folder the executable resides in. I will ask you to send this file to me.
- After completion you can just delete the complete folder.

<u>The Experiment Stages</u>

<u>Stage 1 - Welcome</u>

This is the stage you are in right now. This stage explains the purpose of the experiment. You are also informed about the structure of the overall process. This gives an idea of what expects you.

<u>Stage 2 - Questions</u>

You will be asked to provide some statistical information. All questions are optional. This means you do not have to answer any question that you do not like.

<u>Stage 3 - Explore</u>

This section allows you to investigate the information that is presented to you. It is completely up to you how much time you invest, you may skip over it or spend hours. I can only recommend that you keep it real.

<u>Stage 4 - Task</u>

You will be asked to find a specific piece of information within the information presented to you.

<u>Stage 5 - Test</u>

You will be asked a small number of general questions about the same information

space.

Stage 6 - Thank You

There is no task associated with this stage. You will be asked to send me a file that was generated by this application. All the required information will be supplied.

The File

When you start, the tool the folder will look something like this:
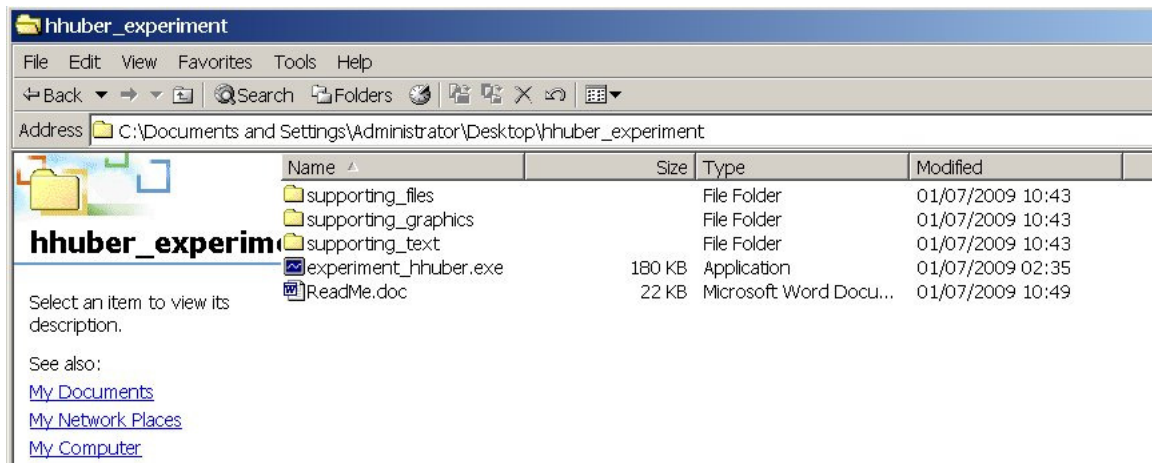
After completion the file addressed above will show up and the folder will look something like this:
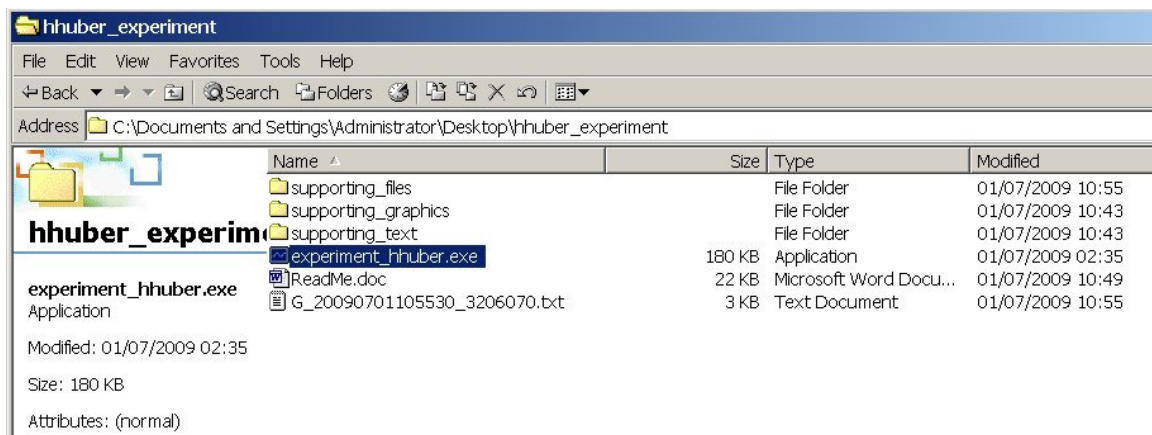
I will require that newly created file (in this case *G_20090701105530_3206070.txt*, it could just as well look something like this *G_20090701105530_3206070.txt*).

Further information will be provided in the course of the experiment process. Please feel free to let me know if you have any questions either before or after completion.

Thanks again!

AB-4: Sample Email – English (Unknown Individuals)

```
Subject: Request for Participation (MSc Experiment)
```

Hello,

I am a student at the DIT School of Computing completing my postgraduate degree course (MSc in Computing (Knowledge Management)) with the dissertation. The latter focuses on visualisation and knowledge maps.

For the experimental part of my dissertation I developed a small program. I deployed it to test my hypothesis that, visually orientated information presentation leads to a more successful transfer of knowledge.

I would appreciate it if you could find the time to participate in the experiment. The executable and all supporting files are lumped together in a zip file. I assure you that the file does not contain any kind of malicious code.

The zip file and further explanatory notes are located on my supervisor's DIT web site.

http://www.comp.dit.ie/dgordon/Helmut_Experiment/

The program does not require installation. It only guides the participant through the process, displays information and records responses and actions within the boundaries of the application. On completion the gathered information will be written to a local text file. The participant will be asked to send that text file as an email attachment to me.

– The file does not identify the participant.
– The participant's email addresses will not be passed on
     to any third party under any circumstances.

I chose this approach since I wish to gather quantitative as well as qualitative data. There is a serious lack in research data as far as the former is concerned.

This approach of course creates a number of barriers for potential participants; thus the number of returns will be reduced. I therefore would greatly appreciate your assistance by participating.

Sincerely,

Helmut Huber

AB-5: Sample Email – German (Known Individuals)

```
Subject: Bitte um Teilnahme (MSc Experiment)

Hallo XXXXX,

Das Experiment fuer meine Diplomarbeit is nun hochgeladen. Die Ausfuehrbare
und alle Hilfsdateien sind in eine ZIP-Datei verpackt. Es ist alles auf
Englisch, aber das ist ein Teil des Experiments.

Diese ZIP-Datei muesstest Du Dir runterladen und entpacken. Danach braucht
nur das Programm gestartet zu werden.

Ich habe die Funktionalitaet des Programms minimalst gehalten. Ich will keine
potentiellen Teilnehmer mit Systemfunktionen wie dem automatischen Versenden
von Emails oder FTP-Verbindungen abschrecken.

Das Program fuehrt Dich lediglich durch den Process, zeigt Informatioen an
und zeichnet intern auf was Du so machst and was Du fuer Antworten gibst. Am
Schluss wird eine Datei in den Ordner geschrieben von dem aus Du das Programm
gestartet hast.

Diese Datei brauche ich dann als Anhang in einer Email an diese Emailadresse.
Die ZIP-Datei und weitere Erklaerungen befinden sich auf der DIT Webseite
meines Betreuers.

http://www.comp.dit.ie/dgordon/Helmut_Experiment/

Ich waere Dir sehr dankbar, wenn Du diese Email an Deine Freunde und
Bekannten mit der Bitte um Teilnahme weiterleiten koenntest.

Beste Gruesse und Vielen Dank,

Helmut
```

APPENDIX C: FULL SAMPLE EXPERIMENT LOG

The following is a log file as created by one of the participants. The header section has been transposed for better readability.

FileName; T_20090707002147_218231156.txt
Header ;Header
Mode; Tabular
TaskResponse; linen
TaskStatus ;Incorrect
ProjectStart; 218231156
ProjectCompletion; 218905203
ProjectDuration; 674047
IntroStart; 218231156
IntroCompletion; 218240359
IntroDuration; 9203
StatsStart; 218241546
StatsCompletion; 218312359
StatsDuration; 70813
ExplorationStart; 218312375
ExplorationCompletion; 218635953
ExplorationDuration; 323578
TaskStart; 218636234
TaskCompletion; 218804312
TaskDuration; 168078
TestStart; 218804593
TestCompletion; 218905203
TestDuration; 100610

FileName	;StatisticalQuestions	;Question Num;Question;Answer;
T_20090707002147_218231156.txt	;StatisticalQuestions	;0;Which age group do you belong to?;31 - 40;
T_20090707002147_218231156.txt	;StatisticalQuestions	;1;Are you male of female?;Male;
T_20090707002147_218231156.txt	;StatisticalQuestions	;2;Do you wear corrective lenes (glasses, contacts)?;Yes;
T_20090707002147_218231156.txt	;StatisticalQuestions	;3;Are you left-handed?;No;
T_20090707002147_218231156.txt	;StatisticalQuestions	;4;What is the main activity of your life about?;Handling Technology (Computing);
T_20090707002147_218231156.txt	;StatisticalQuestions	;5;What is your first language?;English;
T_20090707002147_218231156.txt	;StatisticalQuestions	;6;Do you use English on a daily basis?;Exclusively;
T_20090707002147_218231156.txt	;StatisticalQuestions	;7;To what extent do you work with computers?;At work constantly;
T_20090707002147_218231156.txt	;StatisticalQuestions	;8;In learning, what works best for you?;A Combination of Both;
T_20090707002147_218231156.txt	;StatisticalQuestions	;9;Are you familiar with the making of Sauerkraut?;Somewhat familiar with it;

FileName	;Exploration	;Event;Object;Index;File;Start;End;Duration;
T_20090707002147_218231156.txt	;Exploration	;ExplorationStart;Container;-1;NONE;218312359;218340312;27953;
T_20090707002147_218231156.txt	;Exploration	;FormMove;Container;-1;NONE;218340312;218353140;12828;

T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;2;f_02_Rain.txt;218353140;218353156;16;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;3;f_03_harvested.txt;218353156;218353187;31;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;1;f_01_needs.txt;218353187;218353640;453;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218353640;218353921;281;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;0;f_00_right_cabbage.txt;218353921;218353968;47;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;2;f_02_Rain.txt;218353968;218354171;203;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;4;f_04_summer.txt;218354171;218354859;688;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;2;f_02_Rain.txt;218354859;218354890;31;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;0;f_00_right_cabbage.txt;218354890;218355125;235;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;1;f_01_needs.txt;218355125;218355406;281;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;3;f_03_harvested.txt;218355406;218355671;265;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;2;f_02_Rain.txt;218355671;218355968;297;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;4;f_04_summer.txt;218355968;218356421;453;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218356421;218356468;47;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;5;f_05_manual_cutting.txt;218356468;218356515;47;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218356515;218357109;594;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;15;f_15_curing.txt;218357109;218357125;16;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;17;f_17_time.txt;218357125;218357437;312;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;15;f_15_curing.txt;218357437;218357468;31;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218357468;218358062;594;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;9;f_09_rythm.txt;218358062;218358093;31;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218358093;218358656;563;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;8;f_08_demands.txt;218358656;218358687;31;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;6;f_06_right_amount.txt;218358687;218358718;31;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218358718;218358750;32;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;3;f_03_harvested.txt;218358750;218358765;15;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;2;f_02_Rain.txt;218358765;218358781;16;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;0;f_00_right_cabbage.txt;218358781;218358828;47;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218358828;218359109;281;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;0;f_00_right_cabbage.txt;218359109;218359140;31;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;2;f_02_Rain.txt;218359140;218359156;16;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;4;f_04_summer.txt;218359156;218359187;31;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218359187;218359187;0;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;5;f_05_manual_cutting.txt;218359187;218359203;16;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;7;f_07_pressure.txt;218359203;218359218;15;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;9;f_09_rythm.txt;218359218;218359234;16;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218359234;218359234;0;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;11;f_11_requires_little.txt;218359234;218359265;31;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;13;f_13_is_done_by.txt;218359265;218359265;0;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218359265;218359312;47;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;16;f_16_takes.txt;218359312;218359406;94;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;18;f_18_calls_for.txt;218359406;218359468;62;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218359468;218360109;641;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;19;f_19_environment.txt;218360109;218360375;266;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;17;f_17_time.txt;218360375;218360437;62;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218360437;218402984;42547;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;2;f_02_Rain.txt;218402984;218403234;250;
T_20090707002147_218231156.txt   ;Exploration   ;HoverOver;TableCell;0;f_00_right_cabbage.txt;218403234;218404000;766;
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T_20090707002147_218231156.txt   ;Exploration   ;ClickFileClose;SubContainer;-1;NONE;218618406;218618703;297;
T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218618703;218618734;31;
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T_20090707002147_218231156.txt   ;Exploration   ;ClickFileOpen;TableCell;19;f_19_environment.txt;218619156;218631828;12672;
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T_20090707002147_218231156.txt   ;Exploration   ;FormMove;Container;-1;NONE;218632125;218635953;3828;
T_20090707002147_218231156.txt   ;Exploration   ;SectionExit;Section;-1;NONE;218635953;0;0;

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T_20090707002147_218231156.txt   ;TaskTracking   ;HoverOver;TableCell;17;f_17_time.txt;218661125;218661156;31;
T_20090707002147_218231156.txt   ;TaskTracking   ;HoverOver;TableCell;15;f_15_curing.txt;218661156;218661843;687;
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T_20090707002147_218231156.txt   ;TaskTracking   ;FormMove;Container;-1;NONE;218662031;218666859;4828;
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T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218745093;218745437;344;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;12;f_12_salt.txt;218745437;218746140;703;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;14;f_14_layers.txt;218746140;218746171;31;
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T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;15;f_15_curing.txt;218746203;218746609;406;
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T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;9;f_09_rythm.txt;218746953;218747171;218;
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T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218747656;218748000;344;
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T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;16;f_16_takes.txt;218749593;218749937;344;
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T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;11;f_11_requires_little.txt;218750296;218750765;469;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;10;f_10_seasoning.txt;218750765;218750796;31;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;12;f_12_salt.txt;218750796;218751578;782;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;14;f_14_layers.txt;218751578;218751593;15;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218751593;218751625;32;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;15;f_15_curing.txt;218751625;218751640;15;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;17;f_17_time.txt;218751640;218753296;1656;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;15;f_15_curing.txt;218753296;218753359;63;
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T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;13;f_13_is_done_by.txt;218753437;218753546;109;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;11;f_11_requires_little.txt;218753546;218753703;157;
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T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218758343;218758406;63;
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T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;14;f_14_layers.txt;218763593;218763625;32;
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T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;0;f_00_right_cabbage.txt;218767421;218767750;329;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;2;f_02_Rain.txt;218767750;218767859;109;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;4;f_04_summer.txt;218767859;218767937;78;
T_20090707002147_218231156.txt    ;TaskTracking    ;FormMove;Container;-1;NONE;218767937;218768000;63;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;5;f_05_manual_cutting.txt;218768000;218768265;265;
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T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;12;f_12_salt.txt;218769343;218769750;407;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;14;f_14_layers.txt;218769750;218770796;1046;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;12;f_12_salt.txt;218770796;218770968;172;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;13;f_13_is_done_by.txt;218770968;218771000;32;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;11;f_11_requires_little.txt;218771000;218771312;312;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;13;f_13_is_done_by.txt;218771312;218771578;266;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;14;f_14_layers.txt;218771578;218771625;47;
T_20090707002147_218231156.txt    ;TaskTracking    ;FormMove;Container;-1;NONE;218771625;218771828;203;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;15;f_15_curing.txt;218771828;218772156;328;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;17;f_17_time.txt;218772156;218772187;31;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;19;f_19_environment.txt;218772187;218772578;391;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;17;f_17_time.txt;218772578;218772968;390;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;15;f_15_curing.txt;218772968;218773031;63;
T_20090707002147_218231156.txt    ;TaskTracking    ;FormMove;Container;-1;NONE;218773031;218773187;156;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;15;f_15_curing.txt;218773187;218773359;172;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;16;f_16_takes.txt;218773359;218773531;172;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;18;f_18_calls_for.txt;218773531;218773875;344;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;17;f_17_time.txt;218773875;218773890;15;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;15;f_15_curing.txt;218773890;218773968;78;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;17;f_17_time.txt;218773968;218774125;157;
T_20090707002147_218231156.txt    ;TaskTracking    ;FormMove;Container;-1;NONE;218774125;218774140;15;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;19;f_19_environment.txt;218774140;218774718;578;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;17;f_17_time.txt;218774718;218774734;16;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;15;f_15_curing.txt;218774734;218774765;31;
T_20090707002147_218231156.txt    ;TaskTracking    ;FormMove;Container;-1;NONE;218774765;218774796;31;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;14;f_14_layers.txt;218774796;218774890;94;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;12;f_12_salt.txt;218774890;218774906;16;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;10;f_10_seasoning.txt;218774906;218775015;109;
T_20090707002147_218231156.txt    ;TaskTracking    ;FormMove;Container;-1;NONE;218775015;218775062;47;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;9;f_09_rythm.txt;218775062;218775109;47;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;7;f_07_pressure.txt;218775109;218775203;94;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;5;f_05_manual_cutting.txt;218775203;218775281;78;
T_20090707002147_218231156.txt    ;TaskTracking    ;FormMove;Container;-1;NONE;218775281;218775328;47;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;4;f_04_summer.txt;218775328;218775484;156;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;2;f_02_Rain.txt;218775484;218775812;328;
T_20090707002147_218231156.txt    ;TaskTracking    ;HoverOver;TableCell;4;f_04_summer.txt;218775812;218775843;31;
T_20090707002147_218231156.txt    ;TaskTracking    ;FormMove;Container;-1;NONE;218775843;218775859;16;
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T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;5;f_05_manual_cutting.txt;218775859;218775890;31;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;7;f_07_pressure.txt;218775890;218775937;47;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;9;f_09_rythm.txt;218775937;218775984;47;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218775984;218776015;31;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;10;f_10_seasoning.txt;218776015;218776078;63;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;12;f_12_salt.txt;218776078;218776109;31;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;14;f_14_layers.txt;218776109;218776125;16;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218776125;218776140;15;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;15;f_15_curing.txt;218776140;218776187;47;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;17;f_17_time.txt;218776187;218776218;31;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218776218;218776312;94;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;19;f_19_environment.txt;218776312;218784468;8156;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;17;f_17_time.txt;218784468;218784500;32;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;15;f_15_curing.txt;218784500;218784515;15;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218784515;218784531;16;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;10;f_10_seasoning.txt;218784531;218784546;15;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;9;f_09_rythm.txt;218784546;218784546;0;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;7;f_07_pressure.txt;218784546;218784562;16;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218784562;218784562;0;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;4;f_04_summer.txt;218784562;218784609;47;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;2;f_02_Rain.txt;218784609;218784734;125;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;0;f_00_right_cabbage.txt;218784734;218784750;16;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218784750;218785031;281;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;0;f_00_right_cabbage.txt;218785031;218785109;78;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218785109;218785703;594;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;1;f_01_needs.txt;218785703;218785906;203;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;3;f_03_harvested.txt;218785906;218786000;94;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;0;f_00_right_cabbage.txt;218786000;218786156;156;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;2;f_02_Rain.txt;218786156;218786531;375;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;3;f_03_harvested.txt;218786531;218786546;15;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;1;f_01_needs.txt;218786546;218786781;235;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;3;f_03_harvested.txt;218786781;218786843;62;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218786843;218786968;125;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;4;f_04_summer.txt;218786968;218787046;78;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218787046;218787078;32;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;5;f_05_manual_cutting.txt;218787078;218787171;93;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218787171;218787515;344;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;14;f_14_layers.txt;218787515;218787531;16;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218787531;218787562;31;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;15;f_15_curing.txt;218787562;218787671;109;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;17;f_17_time.txt;218787671;218787734;63;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;19;f_19_environment.txt;218787734;218788078;344;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;17;f_17_time.txt;218788078;218788093;15;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218788093;218788359;266;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;15;f_15_curing.txt;218788359;218788609;250;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218788609;218788671;62;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;14;f_14_layers.txt;218788671;218788703;32;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;12;f_12_salt.txt;218788703;218788796;93;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;10;f_10_seasoning.txt;218788796;218789140;344;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;12;f_12_salt.txt;218789140;218789296;156;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;14;f_14_layers.txt;218789296;218790593;1297;

T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;12;f_12_salt.txt;218790593;218791109;516;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;10;f_10_seasoning.txt;218791109;218791546;437;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;11;f_11_requires_little.txt;218791546;218791906;360;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;13;f_13_is_done_by.txt;218791906;218792046;140;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218792046;218792171;125;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;16;f_16_takes.txt;218792171;218792500;329;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;18;f_18_calls_for.txt;218792500;218792546;46;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;17;f_17_time.txt;218792546;218792562;16;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218792562;218792593;31;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;19;f_19_environment.txt;218792593;218792796;203;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;17;f_17_time.txt;218792796;218793468;672;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;15;f_15_curing.txt;218793468;218793812;344;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;17;f_17_time.txt;218793812;218793875;63;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218793875;218793890;15;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;19;f_19_environment.txt;218793890;218794453;563;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;17;f_17_time.txt;218794453;218794687;234;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;15;f_15_curing.txt;218794687;218795125;438;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;17;f_17_time.txt;218795125;218795250;125;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218795250;218795468;218;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;19;f_19_environment.txt;218795468;218795531;63;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218795531;218802796;7265;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;0;f_00_right_cabbage.txt;218802796;218802812;16;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;2;f_02_Rain.txt;218802812;218802828;16;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;4;f_04_summer.txt;218802828;218802843;15;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218802843;218802859;16;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;7;f_07_pressure.txt;218802859;218802859;0;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;9;f_09_rythm.txt;218802859;218802875;16;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;12;f_12_salt.txt;218802875;218802890;15;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;14;f_14_layers.txt;218802890;218802890;0;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218802890;218802906;16;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;17;f_17_time.txt;218802906;218802906;0;
T_20090707002147_218231156.txt	;TaskTracking	;HoverOver;TableCell;19;f_19_environment.txt;218802906;218802921;15;
T_20090707002147_218231156.txt	;TaskTracking	;FormMove;Container;-1;NONE;218802921;218804312;1391;
T_20090707002147_218231156.txt	;TaskTracking	;TaskCompleted;Section;-1;NONE;218804312;0;0;
FileName	;Test	;Question Num;Question;Answer;
T_20090707002147_218231156.txt	;Test	;0;How many areas of expertise were there?;4;
T_20090707002147_218231156.txt	;Test	;1;Who is the expert for growing cabbage?;I'm not sure;
T_20090707002147_218231156.txt	;Test	;2;Who is the expert for cutting cabbage?;I'm not sure;
T_20090707002147_218231156.txt	;Test	;3;Who is the expert for curing sauerkraut?;I'm not sure;
T_20090707002147_218231156.txt	;Test	;4;Who has an office in Munich?;I'm not sure;
T_20090707002147_218231156.txt	;Test	;5;Who has an office in Salzburg?;I'm not sure;
T_20090707002147_218231156.txt	;Test	;6;Whose phone number is +3534477777?;I'm not sure;
T_20090707002147_218231156.txt	;Test	;7;Are onions an ingredient for sauerkraut?;no;
T_20090707002147_218231156.txt	;Test	;8;Does sauerkraut require lots of salt?;no;
T_20090707002147_218231156.txt	;Test	;9;What is the best season to harvest cabbage?;summer;

APPENDIX D: SAMPLE EVALUATION DATA SETS

This appendix contains the full data evaluation sets that are discussed in Section 6.5.

ParticipantNumber	9	A_Count_CorrectnessIndicator	3
Mode	Tabular	B_Count_CorrectnessIndicator	0
AgeGroup	31 - 40	Tabular_Explore_HoverEvent_Count	180
Gender	Male	Tabular_Explore_HoverEvent_AvgDuration	0.37491667
CorrectiveLenses	No	Tabular_Explore_HoverEvent_MaxDuration	3.469
LeftHanded	No	Tabular_Explore_HoverEvent_MinDuration	0
LifeActivity	Handling Technology (Other)	Tabular_Task_HoverEvent_Count	150
FirstLanguage	German	Tabular_Task_HoverEvent_AvgDuration	0.12478
UseOfEnglish	In social interactions mostly	Tabular_Task_HoverEvent_MaxDuration	1.141
UseOfComputers	Constantly at work and at home	Tabular_Task_HoverEvent_MinDuration	0
PreferredLearningMaterial	A Combination of Both	Graphic_Explore_L1_HoverEvent_Count	0
SauerkrautMakingFamiliarity	Very familiar with it	Graphic_Explore_L1_HoverEvent_AvgDuration	0
ProjectDuration	898796	Graphic_Explore_L1_HoverEvent_MaxDuration	0
IntroDuration	43406	Graphic_Explore_L1_HoverEvent_MinDuration	0
StatsDuration	137516	Graphic_Expore_L2_HoverEvent_Count	0
ExplorationDuration	309625	Graphic_Expore_L2_HoverEvent_AvgDuration	0
TaskDuration	248406	Graphic_Expore_L2_HoverEvent_MaxDuration	0
TestDuration	159562	Graphic_Expore_L2_HoverEvent_MinDuration	0
Exloration_NumberOfFilesOpened	9	Graphic_Task_L1_HoverEvent_Count	0
Exploration_AvgFileOpenDuration	12.34555556	Graphic_Task_L1_HoverEvent_AvgDuration	0
Task_NumOfFilesOpenend	14	Graphic_Task_L1_HoverEvent_MaxDuration	0
Task_AvgFileOpenDuration	5.433071429	Graphic_Task_L1_HoverEvent_MinDuration	0
TaskResponse	cloth	Graphic_Task_L2_HoverEvent_Count	0
TaskStatus	Correct	Graphic_Task_L2_HoverEvent_AvgDuration	0
A_AllMarks	3	Graphic_Task_L2_HoverEvent_MaxDuration	0
B_KMIMarks	0	Graphic_Task_L2_HoverEvent_MinDuration	0

ParticipantNumber	10	A_Count_CorrectnessIndicator	8
Mode	Tabular	B_Count_CorrectnessIndicator	5
AgeGroup	41 - 50	Tabular_Explore_HoverEvent_Count	114
Gender	Female	Tabular_Explore_HoverEvent_AvgDuration	0.32608772
CorrectiveLenses	No	Tabular_Explore_HoverEvent_MaxDuration	10.515
LeftHanded	No	Tabular_Explore_HoverEvent_MinDuration	0
LifeActivity	Handling Technology (Other)	Tabular_Task_HoverEvent_Count	91
FirstLanguage	German	Tabular_Task_HoverEvent_AvgDuration	0.30395604
UseOfEnglish	Practically never	Tabular_Task_HoverEvent_MaxDuration	10.406
UseOfComputers	Constantly at work and at home	Tabular_Task_HoverEvent_MinDuration	0
PreferredLearningMaterial	A Combination of Both	Graphic_Explore_L1_HoverEvent_Count	0
SauerkrautMakingFamiliarity	Very familiar with it	Graphic_Explore_L1_HoverEvent_AvgDuration	0
ProjectDuration	1125641	Graphic_Explore_L1_HoverEvent_MaxDuration	0
IntroDuration	30766	Graphic_Explore_L1_HoverEvent_MinDuration	0
StatsDuration	84547	Graphic_Expore_L2_HoverEvent_Count	0
ExplorationDuration	535750	Graphic_Expore_L2_HoverEvent_AvgDuration	0
TaskDuration	167250	Graphic_Expore_L2_HoverEvent_MaxDuration	0
TestDuration	306172	Graphic_Expore_L2_HoverEvent_MinDuration	0
Exloration_NumberOfFilesOpened	20	Graphic_Task_L1_HoverEvent_Count	0
Exploration_AvgFileOpenDuration	21.19835	Graphic_Task_L1_HoverEvent_AvgDuration	0
Task_NumOfFilesOpenend	11	Graphic_Task_L1_HoverEvent_MaxDuration	0
Task_AvgFileOpenDuration	3.739909091	Graphic_Task_L1_HoverEvent_MinDuration	0
TaskResponse	sauerkraut	Graphic_Task_L2_HoverEvent_Count	0
TaskStatus	Incorrect	Graphic_Task_L2_HoverEvent_AvgDuration	0
A_AllMarks	26	Graphic_Task_L2_HoverEvent_MaxDuration	0
B_KMIMarks	23	Graphic_Task_L2_HoverEvent_MinDuration	0

ParticipantNumber	12	A_Count_CorrectnessIndicator	9
Mode	Graphic	B_Count_CorrectnessIndicator	5
AgeGroup	21 - 30	Tabular_Explore_HoverEvent_Count	0
Gender	Male	Tabular_Explore_HoverEvent_AvgDuration	0
CorrectiveLenses	No	Tabular_Explore_HoverEvent_MaxDuration	0
LeftHanded	No	Tabular_Explore_HoverEvent_MinDuration	0
LifeActivity	Handling Technology (Computing)	Tabular_Task_HoverEvent_Count	0
FirstLanguage	English	Tabular_Task_HoverEvent_AvgDuration	0
UseOfEnglish	Exclusively	Tabular_Task_HoverEvent_MaxDuration	0
UseOfComputers	At work constantly	Tabular_Task_HoverEvent_MinDuration	0
PreferredLearningMaterial	Visual Material	Graphic_Explore_L1_HoverEvent_Count	1
SauerkrautMakingFamiliarity	Never heard of it	Graphic_Explore_L1_HoverEvent_AvgDuration	0.015
ProjectDuration	788359	Graphic_Explore_L1_HoverEvent_MaxDuration	0.015
IntroDuration	159891	Graphic_Explore_L1_HoverEvent_MinDuration	0.015
StatsDuration	59797	Graphic_Expore_L2_HoverEvent_Count	0
ExplorationDuration	75672	Graphic_Expore_L2_HoverEvent_AvgDuration	0
TaskDuration	378625	Graphic_Expore_L2_HoverEvent_MaxDuration	0
TestDuration	114062	Graphic_Expore_L2_HoverEvent_MinDuration	0
Exloration_NumberOfFilesOpened	0	Graphic_Task_L1_HoverEvent_Count	36
Exploration_AvgFileOpenDuration	0	Graphic_Task_L1_HoverEvent_AvgDuration	1.1575
Task_NumOfFilesOpenend	17	Graphic_Task_L1_HoverEvent_MaxDuration	8.047
Task_AvgFileOpenDuration	8.653352941	Graphic_Task_L1_HoverEvent_MinDuration	0
TaskResponse	cutting machine	Graphic_Task_L2_HoverEvent_Count	33
TaskStatus	Incorrect	Graphic_Task_L2_HoverEvent_AvgDuration	0.80969697
A_AllMarks	26	Graphic_Task_L2_HoverEvent_MaxDuration	5.812
B_KMIMarks	22	Graphic_Task_L2_HoverEvent_MinDuration	0.031

ParticipantNumber	24	A_Count_CorrectnessIndicator	2
Mode	Graphic	B_Count_CorrectnessIndicator	0
AgeGroup	31 - 40	Tabular_Explore_HoverEvent_Count	0
Gender	Female	Tabular_Explore_HoverEvent_AvgDuration	0
CorrectiveLenses	Yes	Tabular_Explore_HoverEvent_MaxDuration	0
LeftHanded	No	Tabular_Explore_HoverEvent_MinDuration	0
LifeActivity	Dealing with Data or Numbers	Tabular_Task_HoverEvent_Count	0
FirstLanguage	German	Tabular_Task_HoverEvent_AvgDuration	0
UseOfEnglish	Mostly	Tabular_Task_HoverEvent_MaxDuration	0
UseOfComputers	At work constantly	Tabular_Task_HoverEvent_MinDuration	0
PreferredLearningMaterial	Visual Material	Graphic_Explore_L1_HoverEvent_Count	4
SauerkrautMakingFamiliarity	Somewhat familiar with it	Graphic_Explore_L1_HoverEvent_AvgDuration	2.3905
ProjectDuration	356883	Graphic_Explore_L1_HoverEvent_MaxDuration	9.391
IntroDuration	30872	Graphic_Explore_L1_HoverEvent_MinDuration	0.031
StatsDuration	77719	Graphic_Expore_L2_HoverEvent_Count	0
ExplorationDuration	59280	Graphic_Expore_L2_HoverEvent_AvgDuration	0
TaskDuration	53212	Graphic_Expore_L2_HoverEvent_MaxDuration	0
TestDuration	135596	Graphic_Expore_L2_HoverEvent_MinDuration	0
Exloration_NumberOfFilesOpened	0	Graphic_Task_L1_HoverEvent_Count	9
Exploration_AvgFileOpenDuration	0	Graphic_Task_L1_HoverEvent_AvgDuration	0.59944444
Task_NumOfFilesOpenend	0	Graphic_Task_L1_HoverEvent_MaxDuration	4.258
Task_AvgFileOpenDuration	0	Graphic_Task_L1_HoverEvent_MinDuration	0
TaskResponse	cabbage	Graphic_Task_L2_HoverEvent_Count	0
TaskStatus	Incorrect	Graphic_Task_L2_HoverEvent_AvgDuration	0
A_AllMarks	4	Graphic_Task_L2_HoverEvent_MaxDuration	0
B_KMIMarks	2	Graphic_Task_L2_HoverEvent_MinDuration	0

APPENDIX E: THE 7 PRINCIPLES OF EXPERIMENTAL KNOWLEDGE MAPPING

1. Release an Initial Prototype ASAP.

2. Visual Representations Necessitate Iteration.

3. Keep it Simple.

4. Never Assume an Equivalent Technical Vocabulary in Your Audience.

5. People have Different Preferences in terms of Interfaces.

6. People use Different Types of Computers.

7. Visualisation is a Multifaceted Research Area.