USING COMPUTER-BASED COGNITIVE TOOLS TO ENABLE CRITICAL THINKING

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ABSTRACT

The Institute of Public Administration (IPA) is the Irish national centre for development of best practice in public administration and management. The setting for this study is the information systems (IS) department of the IPA. In the time frame of this study the IPA undertook an Institute-wide re-appraisal of teaching and learning, including higher order thinking skills and the use of e-learning. The aim was to investigate the relationship between critical thinking and technology and the extent to which computer-based tasks could support the development of higher order thinking skills. The research is best described as a small-scale case study in which 17 computer science student-subjects participated. The two principal data collection methods used were authentic computer-based critical thinking tasks (COGITASKs) and online discussions (OLD). The COGITASK requires student teams to construct an artefact using authentic general purpose Hypermedia and Modelling tools. On completion of each COGITASK, each individual student records in an OnLine Discussion forum (OLD) a narrative account of their impressions of what they have learned. The COGITASK generates quantitative data on critical thinking performance, the OLD generates qualitative data about student perceptions of their performance on tasks. The data is analysed using exploratory data analysis and content analysis. The analysis is conducted within a theoretical framework that describes critical thinking as constructive, cognitive, metacognitive and knowledge-based. The research is situated in the natural, authentic context of the IPA classroom, since these tasks are an integral part of instruction on the computer science course. Findings indicated that although, overall, students performed well, across tasks they performed less well on some planning, analysis and application aspects requiring deep understanding and metacognition. However, by triangulating performance and perception data, tools did seem to enable development of skills by making visible certain effects. Eight such effects are discussed. Reflecting, the aim throughout to relate theory to practice the study concludes by translating findings into non-prescriptive, practical guidelines for (IPA) teachers.

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DEDICATION

To my parents

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I wish to acknowledge the support I received from the Institute of Public Administration, who funded my studies. I also wish to acknowledge the insightful comments and general guidance I received from my thesis supervisor, Dr. Rachel Pilkington.

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LIST OF ABBREVIATIONS

COGITASK	An authentic 'design and make' critical thinking task in which students construct an artefact using authentic Hypermedia and Modelling tools. It is used as a data collection method.
OLD	An OnLine Discussion task (OLD), in which each individual student records a narrative account of their impressions of what they have learned as a result of completing the COGITASK. It is used as a data collection method.
IPA	Institute of Public Administration (IPA), Dublin, an accredited college of the National University of Ireland (NUI) which provides training and education for the Irish public sector.
NUI	National University of Ireland, an umbrella organisation for Irish universities
ICT	Information and communication technology
NDP	*National Development Plan 2007-2013(for* Rep. of Ireland)
MS	The Marking Scheme (MS), used to score the data collected from each COGITASK.
NCCS	National Council for Curriculum and Assessment
CMOD	Center for Management and Organisation Development
IS	Information systems
MIS	*Managing Information Systems,* an IPA course which explores the management and organisational context of information systems (IS). It is the setting of this research study.
DSS	Decision Support Systems (DSS), a type of information system (IS)
EIS	Executive Information System, a type of information system (IS), which provides senior managers with planning and control information. EIS COGITASK is a modelling task which requires students to design an EIS.
BPR	Business Process Reengineering, an approach to the radical redesign of organisations, enabled by IS. BPR COGITASK is a modelling task which requires students to redesign a business process.
CAI	Computer-Aided Instruction

ITS	Intelligent Tutoring Systems
CTP	Critical thinking performance, the score derived from the marking of each of each COGITASK
QL	Lower quartile
QU	Upper quartile
CSCL	Computer Supported Collaborative Learning
VLE	Virtual Learning Environment
ID	instructional design
DBRC	Design-Based Research Collective

CHAPTER 1: THE INSTITUTE OF PUBLIC ADMINISTRATION (IPA) – CONTEXT OF THE STUDY

1.1 Introduction and Purpose

This chapter describes the context of this research, which is set in the Institute of Public Administration (IPA), Dublin. In particular, the purpose of the chapter is to show how changes in the IPA environment – in society at large, in technology, learning, educational policy, the Irish public sector and in university regulation – have all highlighted, if on occasion overstated , the renewed importance of both critical thinking and technology in the educational policy for this sector. The chapter is divided into two sections, the first of which looks at changes in the wider IPA environment; the second looks at the IPA's more immediate environment and some internal contextual issues. Since the IPA is the premier agency for public sector development in Ireland, it must be responsive to such changes and ensure that the importance of critical thinking and technology in the IPA's environment is reflected in its teaching and learning programmes. This, then, is the setting from which the rationale for this study emerges, since the study focuses on the relationship between critical thinking and technology, used as cognitive tools in the IPA context.

1.2 The Wider Environment

The IPA, established over 60 years ago, is an accredited college of the National University of Ireland (NUI). It provides training, education, research and publication services to individuals and organisations from the Irish public sector (IPA, 2010a). The IPA describes itself as 'the Irish national centre for development of best practice in public administration and public management' (IPA, 2010a).

The IPA receives €4m of its €16m budget from the national coffers – an endorsement by government of the IPA's central role in the development of public servants. Approximately 14000 public servants participate annually in IPA short-term training programs, while there are about 2000 undergraduate and postgraduate students on longer term educational programs.

As the premier agency for public sector development it must be seen to be responsive to the needs of public managers arising out of the rapidly changing public sector environment. These needs include, as we shall see below, the need to be able to think through policies and action plans more critically. Thus *The IPA Draft Corporate Plan* (IPA, 2010b) commits to delivering

> 'relevant training .... and education services to our clients, particularly reflecting the current economic challenges' (Strategy 1.3).

The changes and challenges in the IPA's wider and immediate environment are now forcing the IPA to revaluate its approach to teaching and learning, including a greater emphasis on critical thinking.

1.2.1 The Knowledge Society and Irish Society

Ireland is part of the so-called knowledge society (Drucker, 1993; Hargreaves, 2003). The knowledge society uses information and communication technology (ICT) as its chief means of creating and sharing information globally. While we must be on our guard for claims made about the knowledge society, nonetheless, the ability to use tools, technical and thinking skills in such a society appears to be a key requirement.

According to Carnoy and Castells,

> ‘The distinguishing feature of work in the information age is the centrality of knowledge, especially ‘transportable’ general knowledge’ (1999: 33).

Critical thinking is one example of such general, ‘transportable’ knowledge.

> ‘In the era of the Internet and the information society, where there is much false and incomplete information, critical thinking represents a major qualification for people in deciding what to do or believe’ (Yang et al., 2007a: 18).

One implication of the above for teaching and learning, as Hargreaves notes, is that there must be a shift from the stress on basic literacy and numeracy to the ‘core competencies’ – critical thinking, creativity and the application of knowledge (Hargreaves, 2003).

‘The ongoing relevance of curricula to .... the knowledge society’(NDP, 2007: 175) is not lost on Irish policy makers. Forfás, ‘Ireland’s national policy advisory body for enterprise and science’ (Forfás, 2010), highlights both ICT and critical thinking, which it describes as ‘fundamental’ to the curriculum. Forfás recommends that Ireland focus its efforts on developing these skills, at all levels, as part of our educational policy (Forfás, 2009a: 4, 2009b)

1.2.2 Technology in Society

The period 1990-2010 saw the arrival of the laptop, the mobile phone, the mouse, the Internet and e-mail. The 100 million computers in the world in 1990 rose to two billion by 2007 (Gartner, 2010). In 1993 there were only 130 sites on the World Wide Web.

Today there are several billions. The internet in its turn is spawning a whole host of new applications.

Furthermore, ICT has become completely interwoven into the fabric of our lives, whether this is for booking flights, taxing cars or checking bank accounts.

> ‘The Net has profoundly changed the way we spend money, keep in touch with our friends and get information’ (Levy, 2004:14).

Reflecting this general trend, technologies for *learning* have also proliferated. In her *Learning Tools Directory 2010* Jane Hart lists a total of 1,947 such tools (Hart, 2010).

While there has been a massive increase in learning technologies, not all are convinced of the effectiveness of such tools. Cuban calls into question the degree to which they have had a transformative effect on learning:

> ‘When it comes to higher teacher and student productivity and a transformation in teaching and learning …. there is little ambiguity. Both must be tagged as failures. Computers have been oversold and underused’ (Cuban, 2001:185).

Pilkington points to similar findings in the UK, where ‘teachers were mainly using IT to support basic literacy, numeracy and IT skills’ (Pilkington, 2008: 988).

One of the reasons for these somewhat disappointing results is that training of teachers has not kept pace with changes in technology (Mumtaz, 2000). Similarly, Passey observes

> ‘these results indicate that it is important that there is a deeper understanding of the pedagogy of ICT’ (Passey, 2006: 163).

1.2.3 Trends in Learning

The learning sciences have not been immune to change in the last quarter of a century (Bransford et al., 2002). For instance, the exploration of the potential role of tools in supporting learning has been an important theme in the development of the theory of constructionism (Papert, 1985), for collaboration in learning (Koschmann, 1996), in developing the skills of metacognition (Pintrich, 2002) and in the provision of learner-centered environments (Hannafin and Land, 1997). The use of technology as a tool to support learning has developed continually alongside the development of new technologies (Pilkington, 2008; Lajoie, 2000)

One idea that has remained fairly constant is that of higher order learning. In the 50 years or so that have elapsed since Bloom's taxonomy was published, accounts of learning still point to the importance of higher order outcomes. For instance,

> 'Preparing students to be good problem-solvers, critical thinkers, and lifelong learners has become a critically important educational goal in this 21st century ....[as well as] .... help[ing] students develop higher-order thinking skills' (Liu *et al*., 2004:310).

In addition, contemporary accounts of learning foreground the enabling of higher order thinking skills through the medium of ICT. 'Learning technologies and tools can support students in the learning forms that contribute to the high-level cognitive skills' (Laurillard, 2002:150). Similarly, *Partnership for 21st Century Skills* describes four essential skill sets required in the 21st century. Two of the four skill sets are critical thinking and ICT skills – where ICT is seen as being of value in itself as well as being an enabler of critical thinking (PCS, 2009).

However, in order to facilitate the enabling of higher order thinking skills through the medium of ICT, Laurillard and others point to the need to equip teachers with the necessary technical and pedagogic skills as an important challenge (Laurillard, 2002; David and Foray, 2002: 17). In this regard the provision of guidelines for the teaching of critical thinking using cognitive tools could be a useful function served by this research.

1.2.4 Education Policy in Ireland

The general trends in learning, discussed above, are also reflected in Irish educational policy. *The National Development Plan 2007-2013* for Ireland highlights both higher order outcomes and ICT. Key areas are:

> 'promoting active teaching and learning approaches, nurturing of higher order thinking skills, embedding ICT across the subjects' (NDP, 2007: 175).

Similarly, the policy documents of the Department of Education and its advisory bodies, such as the National Council for Curriculum and Assessment (NCCA), repeatedly seek to

> 'promote the importance of higher order thinking skills, critical thinking, problem solving, collaboration with others, learning to learn…… – key requirements of the knowledge society' (NCCA, 2004a: 10).

As regards ICT, the Department's investment of €252m in ICT is evidence of the importance it attaches to the role of ICT in teaching and learning. Policy makers are clear on how ICT should be used:

> 'ICT adds value to the curriculum when it supports the development of students' higher order thinking skills' (NCCA, 2004a: 34).

However, this can only come about, the NCCA insists, with the professional development of teachers in the use of ICT for teaching and learning. It is critical

> 'to provide all teachers with appropriate training …. and to introduce measures to encourage teachers to make real use of digital technology in their lessons' (NCCA, 2004a: 12).

1.3 The Immediate Environment

In the first section we looked at the wider societal issues affecting Irish education. In this section we examine the main stakeholders in the immediate environment of the IPA – the IPA's public sector customer base and The National University of Ireland (NUI) – as well as some more local contextual issues – the courses, technology, tutors and students – and tease out their implications for the teaching and learning of critical thinking using technology in the IPA.

1.3.1 The IPA's Customer Base – The Irish Public Sector

The Irish public sector is the IPA's main customer. The advent of the knowledge society has meant that the public sector environment, once static and simple, is now complex and dynamic (Daft, 2001). The government's *Strategic Management Initiative* (SMI), *Better Local Government, the Management Information Framework (MIF)* and *the Modernisation Programme* are all high level responses to dealing with this new complexity (Taoiseach, 2010).

Whereas in the past public sector managers might have only been required to translate such government responses into action by applying rules and standard procedures set out for them by government, they are now typically required to rewrite the rules, to be innovative and to apply critical thinking to non-standard, ill-structured, complex problems (cp. Brown et al., 1989: 34-36; Jonassen, 2003: 365-366). Radical solutions to public management issues will include the 'fundamental rethinking' and 'radical redesign' of the business of the public sector (Hammer and Champy, 2006).

Consequently, public sector managers, professionals, and policy makers – the IPA clients of particular interest here – are faced with the challenge of thinking their way through new policies and services. This cannot be done without some training.

The *Framework for Civil Service Training and Development 2004-2008*, the influential, regulatory Strategy for civil servants' training, recognises this. Categories 3 & 4 of the *Framework* list the required 'behavioural competencies' for general managers, professionals and policy analysts (CMOD, 2004: 25). Of particular interest in this context are 'Analytical thinking', 'Conceptual thinking' and 'Decision Making/Judgement' (CMOD, 2004: 23).

The document reiterates the goal of training and development as the creation of

> 'A learning culture which promotes and supports continuous questioning and review of organisational practices and procedures by expanding the boundaries of innovation, creativity and best practice' (CMOD, 2004: 14).

To support this cultural shift, 'this continuous questioning …. of organisational practices', the *Framework* signals the increasing demand in training for (1) higher order, critical thinking outcomes, and (2) more conceptual treatment of training domains.

The IPA, as the national centre of public sector development and education, must be responsive to these demands.

1.3.2 NUI

Just as the Irish public sector is the IPA's main customer, so The National University of Ireland (NUI) is the IPA's main regulator.

NUI is an umbrella organisation for Irish universities. The IPA became an accredited college of the NUI in 2001. NUI accreditation is central to the IPA's 'credentialing' strategy. For instance, Strategy 1.1.5 in the *IPA Draft Corporate Plan* specifically seeks 'to add value', through accreditation, to IPA training and education 'products' (IPA, 2010b).

Accreditation, however, requires that IPA programs conform to NUI standards. Each program submitted for accreditation must provide evidence that students are required to research information, analyse concepts, think critically and synthesise ideas.

The submission for the *Diploma in Computer Studies* was rejected initially by the NUI because of an 'overly vocational, skills-based emphasis'. It was accepted only when the conceptual and analytical content of the program was augmented. Thus higher order outcomes, including those often associated with critical thinking, are sought for NUI accreditation.

Thus any submission to the NUI for accreditation which cannot demonstrate the higher order outcomes sought – including critical thinking – is likely to be unsuccessful.

1.3.3 Courses and Content: The New IPA Course Model

As a specific response to both the public sector's needs and the NUI's regulatory requirements the IPA developed a new course model – 'the accredited programme'. Until the last decade the IPA's annual *Directory of Services* was typified by a preponderance of short (one, two or three day) skills-based courses such as 'Interpersonal Skills', 'Leadership for Supervisors', 'Effective Writing' and so on.

These new accredited programmes are in line with the *IPA Draft Corporate Plan* which endorses a general move in the IPA to 'longer-term development programmes, [focusing] on key aspects of executive development' (Strategy 1.3.2). The accredited programme extends over a one or two year cycle, offering a certificate or diploma on successful completion of one's studies. Thus, the new model is designed to deliver higher order learning, by combining classroom and online methods, mixing the skills-based approach with enhanced conceptual and critical thinking components, which are essential requirements for both the IPA's public sector clients and for NUI accreditation. The accredited programmes include diplomas in health, local government, finance and computing. The *Diploma in Computer Studies* consists of a number of courses, one of which, the *Managing Information Systems* (MIS) course, is the setting for our present study. A full description of MIS now follows:

MIS Course

The *Managing Information Systems* course is a second year subject on the 2-year part-time *NUI Diploma in Computer Studies* (IPA 2010a). The course explores the management and organisational context of information systems (IS). It examines the interrelationship between IS and the organisation's environment, task and social systems. Key themes include IS and customer service, IS and planning (executive systems), IS and process-reengineering, and IS and people.

MIS is not designed to teach technical skills. Its goals are to help students reflect on important concepts relating to IS and organisations and to foster higher order skills such as analysing, applying, evaluating and creating. MIS focuses more on the *Managing* part of the course title than on the *Information Systems* part. This is not to say that MIS is a purely 'theoretical' course, as it encourages students to see that ideas have practical implications and emphasises the importance of students applying ideas critically to their own situation. Thus, students learn not only IT planning concepts but also how to formulate an IT plan.

MIS is taught by means of lectures, workshops, group discussions, case studies and by the use of group-based extended exercises – tool-based critical thinking tasks which require students to build some artefact. Students are briefed before each exercise, given guidance in the course of it and contribute reflections about their learning on its completion.

MIS consists of four two-day modules separated by about a month, an interval in which students are required to do certain specified reading and contribute to certain online discussions. Students are assessed on both the practical and academic elements of the courses.

1.3.4 IPA Technology

The IPA currently has the following technological tools available to it: Moodle, a virtual learning environment; office automation technologies such as Word, Excel and PowerPoint, content development technologies such as Articulate and Course Genie, discussion tools, video conferencing, webinar technologies, chat rooms and social networking tools as well as a wide range of hardware such as digital video and stills cameras.

From the purely technical point of view, the IPA has already sufficient learning technologies and tools to support the process of teaching and learning, including the teaching and learning of critical thinking. Yet the IPA, like other educational organisations, such as those referred to earlier by Cuban, has not been particularly successful in adopting these technologies for learning. Evidence for this comes both from the students and the teaching staff – the subjects of the next two subsections.

1.3.5 IPA Students

We turn our attention now to IPA students. The description below attempts to convey a semi-personal account of their background.

MIS Student Profile

MIS students are typical of other IPA students on accredited programmes. They are between 25 and 35 years of age. They are evenly divided between male and female. Students are often married and as a result their study time is more constrained than that of a typical university undergraduate. About 50% of students have prior qualifications such as a degree or, more commonly, a Diploma. MIS students are quite typical of IPA students on other accredited programs in that they are typically mature, full-time public servants who either work in an Information Systems department or aspire to working in such a department. Those who work in IS departments are trouble shooters, supervisors or team leaders. Students come from all over Ireland and travel to Dublin for their courses. Their studies are normally funded by their organisation. They are released en bloc for the formal part of their studies by their government department. In a year this can amount to between 22 and 30 days. For the MIS course the students are required to attend four blocks of two days each. These part-time students, therefore, differ from typical 18 to 20 year old full-time university counterparts. They do not tend to hang around with one another but prefer to return to their families. They do not frequent the student bar (there isn't one in the IPA) but tend to socialise with work colleagues, family or friends not on the course.

This background partly explains some of the comments in the detailed 60-page internal IPA report, *Online Learning in the IPA: A Discussion of Issues* (IPA, 2006). According to the study, tutors report that students' understanding is often 'shallow', they 'focus on irrelevancies', 'they cannot structure an essay', 'construct an argument' or apply what they learn. IPA tutors maintain that students neither pursue learning as a goal in itself nor for its work relevance but for career advancement.

Constrained by time, student responses to learning and assessment can be strategic (Goodyear *et al*., 2003: 151). They learn by rote and reproduce the 'notes'. The short essay-type assignments, at least in the way that they are used in the IPA, do not sufficiently require students to engage in in-depth analysis, to use the richness of their prior knowledge, to critically apply the domain concepts to their work, to formulate coherent arguments and to support them with evidence. Rewarded for accurate reproductive strategies, it is not surprising that students do not develop the critical thinking now required by public management.

The new accredited programmes, however, offer greater latitude for changes in assessment procedures. CIW, a constituent course of the accredited *Diploma in Computer Studies*, is a good example of how change in this area can be brought about. The course texts present a detailed, sometimes conceptually complex treatment of web technologies. Two years ago, students were assessed by two internationally recognised, professional online examinations consisting of multiple-choice questions. Students could obtain a successful outcome by recalling port numbers for a specified internet service or spotting the punctuation error in an HTML statement or remembering the numbers in an IP address. Not surprisingly, students never 'bothered' to really come to grips with the conceptual complexity of the subject matter. Instead they prepared for their tests by memorising facts and by studying hundreds of questions from previous CIW examinations which they can download from the Internet. Not unlike other students, their skills and ‘understanding of content’ were ‘deficient’ because they were ‘required to represent what they [knew] in only one way’ (Jonassen and Carr, 2000: 166).

This has changed. Students still sit their online examinations. Now, however, IPA Diploma students are also required to engage in an authentic critical thinking task – the design and development of a web site using web-authoring (cognitive) tools. This act of construction tests not recall but rather obliges students to address all the aspects of critical thinking – constructive, cognitive, metacognitive and knowledge – that will be discussed in the next chapter.

1.3.6 Tutors

Strategies 3.1.1 and 3.1.2 of the *IPA Draft Corporate Plan* recognise the ongoing requirement to support all aspects of the tutor’s work and practice, in the delivery of higher order outcomes such as critical thinking. Pedagogic and technical training are necessary ‘to develop the competencies required to deliver high-quality services to the Institute’s clients’ (IPA, 2010b). This strategy supports the move from short skills-based courses to the development of the IPA as a centre of excellence – a ‘source of expertise in public administration, public management and public policy’ – whose training and education focus, primarily, on the delivery of high-quality, professional, higher order outcomes (IPA, 2010b).

When asked to identify their training needs, IPA tutors – like third level tutors elsewhere (Bates, 2000) – ranked at the top of their list a lack of formal training in pedagogy, especially in relation to higher order skills (IPA, 2006). Some 70% also report a ‘lack of technological competence’. Nonetheless, the majority make an informal, restricted use of word processors, presentation tools, email and internet to support learners where they can see an opportunity to ‘add value to learning’ or ‘do what they cannot easily do by traditional means’ (IPA, 2006).

The limited adoption of such learning technologies and tools has not been helped by the lack of a systematic training program. But training in itself is no guarantee of technological adoption (Cuban, 2001). For instance, a ten-day modular training program in ‘Online Course Design and Development’ was held for nine members of IPA staff. The course, which included treatment of both pedagogic and technological issues, largely focused on helping IPA tutors develop short online tutorials using a web authoring tool, *Dreamweaver.* The post-course evaluation revealed some serious defects: The technology used was unfamiliar, difficult and often frustrating for IPA novices, the development of tutorials was time consuming, the end product slight in proportion to the effort expended and, importantly, the behaviorist assumptions, such as the need for predefined measurable objectives did not fit well with the higher order learning outcomes which most IPA tutors are trying to facilitate (cp. Munro, 2000). One year later none of the tutors had gone on to incorporate such web-based tutorials in any of their programs.

The ‘Online Course Design and Development’ programme gives some clues as to how the IPA tutors might wish to upgrade their pedagogic and technical competence. What they are most looking for is ‘useful ideas’, ‘rules of thumb’ (cp. Goodyear et al., 2003: 8) grounded in research but oriented to ‘best practice: what works, what doesn’t’ about effective uses of 'straightforward' learning technologies and tools that they can accommodate, 'without great effort', into their higher order learning programs (IPA, 2006). IPA tutors require guidelines to bridge the gap between the research complexity and routine practice that will provide them with ideas that can be applied to higher order learning. It is hoped that this thesis might provide a basis for a draft set of guidelines for the teaching of critical thinking using cognitive tools which will act like a 'bridgehead' (Saunders et al., 2005:43) to ultimately facilitate the advance of consensual change in the IPA since, as Fullan notes, 'educators need the tools to engage in change productively' (Fullan, 1993: 2).

1.4 Chapter Summary

To re-cap: In addition to changes in the IPA's wider environment, which are all pointing to a growing sense of the importance of both critical thinking and ICT, there is an increasing requirement in the IPA's immediate environment – the IPA's main customer, the public sector, and from its main regulator, the NUI – for the greater incorporation of higher order thinking skills into its programmes. In response to this the IPA has developed new accredited programmes to replace its short skills-based courses. These programmes, blending classroom and online technological components, place greater emphasis on higher order outcomes, including critical thinking. However, research is yet to establish, in any empirical detail, the relationship between critical thinking and ICT (cognitive tools). IPA tutors who receive little training in either pedagogy or ICT have limited expertise in designing instruction for critical thinking using ICT. Thus, the rationale for this study, which sets out to investigate the relationship between ICT cognitive tools and critical thinking and to outline its possible implications for teaching and learning in the IPA, is clearly related to the IPA's environments(s) and the review of its approach to teaching and learning.

A short personal reflection appears immediately below. I have decided to incorporate these reflections as a feature of each chapter as a way of helping the reader to gain insights into my own motivations and roles in conducting research on my teaching in this context and my relationship with the participants in the research. I hope these reflections will help clarify issues of reflexivity and subjectivity, including methodological and ethical tensions between insider and outsider research, the roles of researcher and practitioner and my choices in scoping the research and in collecting and interpreting data. In this first reflection I consider what drew me to this topic, what I considered important to study and how I see the research in relation to my own learning and teaching experiences. The reflection offers some information on myself and my interests which, hopefully, will provide useful context for the reader.

1.5 Reflection

I am 55 years of age, Irish, living in Dublin and teaching in the IPA. Initially, I studied Ancient Classics (MA). Later I studied Statistics in Trinity College and Systems Analysis/ Information Systems in the IPA and various other colleges. After a long break I took an MSc in Learning Technologies in Lancaster. Although I teach information systems, my principal interests are in (classical) literature and language(s) – I write poetry and teach Greek in my spare time.

I have spent virtually all my working life in the IPA, firstly in management training (both the quantitative and qualitative aspects) and later teaching information systems. I am now 'Head' of IT Training and Education. As teacher, I think of my role more as facilitator than lecturer, my classes less lectures than workshops, in which students discuss and 'do' things. My role, as I see it, is partly about teaching in the traditional sense but more about helping students to learn, to come to understandings of the significance of what they say and do. This approach has always seemed natural to me but has, no doubt, been influenced by the trend, referred to above, towards constructivism. As 'Head of IT', much of my efforts are devoted to programme planning and formulating responses to the customers' needs, described in the main narrative above.

What has drawn me to a study of critical thinking and cognitive tools? Mention has been made of ICT as a key enabler of the knowledge society and critical thinking. Since I teach information technology and since my main professional interest is in the relationship between technology, tools and learning, this seems a natural enough topic choice.

But there are other, slightly more personal reasons. I have always been interested in how I, myself, and others learn. In the course of 30 years of teaching I have been struck by a number of recurring issues:

- Students almost invariably performed worse on the ‘analytical’ or ‘critical thinking’ aspects of assessment than on the ‘descriptive’.
- Students valued being able to apply theoretical ideas in practice (using tools, for instance) and yet this was the area where they often had the most difficulty.
- In tackling tasks/problems, students often had (apparently) no idea of where they had ‘gone wrong’, yet with support could generally point to the causes of their difficulty.
- Students’ negative misconceptions of their own ability were sometimes devastating in their effect.
- Many students, who had passed their exams, were leaving the Institute with a rather superficial, uncritical understanding.

So, I have been coming to my subject for some time, wondering how the above issues might be addressed, if there was a better way to teach and where all of these things might fit in with critical thinking. The thesis offers me the opportunity to explore some of these questions.

I have said something about my background, my role and my motives. Before I finish, let me say a word about the reflections themselves. Chapter 1 addresses the context of the study. C*ontextus*, Lat. means ‘woven together’, ‘entwined’. Part of the purpose of these reflections is to show how my research world is interwoven with my personal world, how the researcher is entwined with the teacher, classicist, poet and plain human being.

These reflections allow me speak in a different voice, to introduce feelings or thoughts without having to defend them, to present a perspective different to the main narrative and to operate under a set of rules different from those associated with academic writing. These differences allow me to be somewhat subversive, to undercut what is being said in the main narrative, to suggest misgivings. In other words, to paraphrase Jonassen and Carr (2000), I use the reflections to represent in more than one way what I think and feel.

IPA tutors report that students' understanding is often shallow. In these reflections I attempt to clarify my understanding, to philosophise a little, to look for (deeper) meaning and to interpret the significance of what I am doing – yet, in all this, feeling free to leave matters provisional and 'hanging'. There is no end to the depth of reflection one can engage in, but whether or not the 'real depth' of ourselves is accessible through *thinking* alone is another matter.

CHAPTER 2: CRITICAL THINKING AND COGNITIVE TOOLS – A LITERATURE REVIEW

2.1 Introduction and Purpose

This chapter presents a broad overview of the literature on critical thinking and cognitive tools. Its chief purpose is to provide a theoretical framework for the research and a context for the research questions. The chapter is divided into two main sections. The first deals with the nature of critical thinking, the second with cognitive tools. Drawing on multiple approaches to critical thinking, the chapter develops a framework which characterises critical thinking as constructive, cognitive, metacognitive and knowledge-based. The second section, dealing with cognitive tools, discusses their definition, classification and their potential role in facilitating critical thinking. The chapter shows that while there has been much discourse on the nature of critical thinking, there is a much more limited empirical literature concerning the detailed mechanisms by which cognitive tools may enable certain types of critical thinking. The research questions with which the chapter concludes therefore focus on such detailed study and in particular the strengths and weaknesses in students' critical thinking that the use of such tools may reveal and the implications for teaching in the IPA context.

2.2 Developing a Framework for Critical Thinking

This section first reviews some key definitions and conceptions of critical thinking. It then considers what the essential components of critical thinking might be, and the various approaches to it that have been taken. The section concludes by synthesising the above into a critical thinking framework that will be used to guide this study.

2.2.1 Alternative Definitions and Characteristics of Critical Thinking

John Dewey defined critical thinking as:

> ‘the active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends’ (Dewey, 1933:118).

For Dewey, critical thinking is not passive. The consideration of any question requires active processing and, further, the resultant judgements should be based on evidence – ‘the grounds that support [belief]’.

Edward Glaser further defined critical thinking as:

> ‘(1) an attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experiences (2) knowledge of the methods of logical inquiry and reasoning, and (3) some skill in applying those methods. Critical thinking calls for a persistent effort to examine any belief or supposed form of knowledge in the light of the evidence that supports it and the further conclusions to which it tends’ (Glaser, 1941: 5-6).

Although reminiscent of Dewey, Glaser introduces two further ideas: the first that critical thinking is dispositional, that is, it has something to do with the way we are disposed to look at problems, tasks or situations or, put another way, learning to become critical involves developing attitudes (working habits) that dispose us to routinely, subconsciously or automatically approach certain types of problem in a particular way. The second key idea is that critical thinking requires knowledge – the kind of generic or general skills that can be consciously applied to many domains of learning or classes of problem. The generic skills or ‘abilities’ that Glaser had in mind include the ability

> ‘(a) to recognize problems …. (c) to gather and marshal pertinent information, (d) to recognise unstated assumptions and values …. (f) to interpret data, (g) to appraise evidence and evaluate statements’ (Glaser, 1941: 6).

A half century later, *The Delphi Report* echoes this list of cognitive skills when it summarises the expert consensus of a large number of American academics on critical thinking as follows:

> ‘We understand critical thinking to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference’ (Facione, 1990: 2).

Like Glaser, Facione lists the cognitive skills of critical thinking, such as interpretation, analysing, evaluation and so on. Along with these skills Facione introduces the idea that critical thinking is self-regulatory. Critical thinking is not just cognitive, it is also metacognitive – a central theme in recent accounts of critical thinking (Paul et al., 1993).

Robert Ennis expands somewhat on this self-regulatory component in defining critical thinking as ‘reasonable, reflective thinking that is focused on deciding what to believe or what to do’ (Ennis, 1991, 1992).

Ennis’s definition discriminates between two goals of critical thinking: knowing (1) ‘what to believe’ and (2) ‘what to do’. Similarly, Scriven and Paul (2008) describe critical thinking as ‘a guide to belief and action’. Thus, the definitions remind us that the purpose of critical thinking is closely related to action. It also reminds us that definitions of knowledge have often sought to distinguish between ‘knowing that’ (factual and conceptual knowledge), and ‘knowing how’ (procedural knowledge linked to active processes such as reasoning).

Thus, whilst there are differences in these definitions of critical thinking there are also some common themes. For instance, most accounts agree that critical thinking is active and constructive, involving persistent effort in the construction of arguments or beliefs, artefacts or actions. Secondly, critical thinking requires the use of cognitive skills such as analysing, interpreting and evaluating. In addition, metacognitive skills, such as the capacity to reflect on and regulate our actions, are now seen as an important aspect of critical thinking. Moreover, critical thinking also requires knowledge (both factual and conceptual knowledge as well as 'knowledge of methods of logical inquiry and reasoning').

Sociocultural accounts of cognition add a further social and collaborative dimension to our conception of thinking (Vygotsky, 1978). For instance, Nardi (2001), in comparing activity theory with cognitive science, argues that activity theory is essentially a social theory of consciousness and therefore seeks to define all mental functioning such as thinking, as a product of our social interactions – the result of an attempt to make sense of experiences and encounters with significant others. This sociocultural perspective is explored further in a later sub-section.

In the remainder of this section I argue toward a framework for critical thinking based upon five key perspectives found in the literature: constructive, cognitive, metacognitive, sociocultural and dispositional/affective. I also consider the domains of knowledge required based on a discussion of these alternative perspectives before offering my own synthesis or framework for study. The proposed framework emphasises the need for a theory of critical thinking which involves synthesising (construction) as well as analysing (inductive as well as deductive reasoning), includes metacognitive (self-regulating processes) as well as cognitive skills and domain-specific as well as general knowledge (factual, conceptual and methodological). In arriving at my own framework I acknowledge that the constructive, cognitive and metacognitive aspects are foregrounded as particularly important for the purposes of my research and that whilst aspects of sociocultural and dispositional theory are also acknowledged as important to the study of critical thinking in learning contexts (particularly collaborative learning) they are not the primary focus for this study.

2.2.2 Taking a Constructive Approach

Dewey, as discussed above, characterises critical thinking as an ‘active’ process based on seeking evidential supports for beliefs. Scriven and Paul describe it in similar terms as the ‘process of actively and skilfully conceptualising, synthesising and/or evaluating’ (Scriven and Paul, 2008: 1).

Facione also points to the constructive nature of critical thinking when he defines it as ‘the ability to properly construct and evaluate arguments’ (Facione, 1986: 222). Cottrell, similarly, describes it as a process for ‘working out whether we believe what we see or hear’ (Cottrell, 2005: viii). ‘Working out’ is the key phrase here. Beliefs need to be worked out. Critical thinking helps us to construct our beliefs about the world around us. Like Cottrell, Glaser speaks of the ability ‘to reconstruct one's patterns of beliefs’ as being essential for the critical thinker. Finally, Moon expands on the constructive nature of critical thinking, describing it as

> ‘a means of generating new knowledge by processing existing knowledge and ideas using what we have called the tools of manipulation of knowledge (analysis, understanding, synthesis)’ (Moon, 2007: 33).

Constructivism implies that when learners engage in critical thinking they are actively constructing their own knowledge, assimilating and accommodating it to prior knowledge and beliefs (Bransford et al., 2002). This is achieved by constructing conceptual frameworks or schemas which serve to organise knowledge (Fulcher, 2003; Mayer, 2001).

Such frameworks (knowledge schema) consist of interconnected hierarchically arranged facts (propositions) and concepts, cognitive processes which operate on them and the conditions for the application of these. Humans synthesise information by the application of certain cognitive processes, such as assimilation and accommodation. Processes of assimilation are essentially additive, linking new data or propositions into the existing framework without the need to reorganise that framework, whilst accommodation requires modification of the conceptual organisation in order to add the new data.

Research suggests the existence of well-developed frameworks is one of the distinctive characteristics of critical thinkers (Chase and Simon, 1973). Further, it is thought that the overall schema contains multiple specific schemata, including specialised schemata for the purpose and use of individual tools (Baber, 2006). Critical thinkers use frameworks, primarily, in order to categorise information and solve problems effectively and efficiently (Fulcher, 2003; Glaser and Baxter, 2000).

'Making', 'synthesising', 'creating', 'constructing' are all words used to describe the process of construction (Papert, 1985). Humans construct all manner of things: arguments and poems, houses and schools, websites and models. Indeed, there are few human activities that are more essential than constructing (Dalgarno, 2001).

The critical thinking tradition, influenced by cognitive approaches (see immediately below), has, however, focused less on construction than on analysis. Consequently, critical thinking has come to be associated in the minds of many with 'the questioning or inquiry we engage in when we seek to understand, evaluate, or resolve' (Maiorana, 1992).

Bell (1995) exemplifies the analytical emphasis. Bell sets out to teach how to critically analyse secondary sources. The analysis consists of six stages, which include 'analyse definitions', 'analyse evidence' and 'evaluate evidence'. The focus is analytical, namely on how to take arguments apart. Fisher (2001) also offers a set of precepts for critical thinking. Examples include 'identify assumptions', 'judge credibility' of claims, and 'draw inferences'. Once again the focus is on analysis.

The constructivist view values synthesis at least as much as analysis in defining critical thinking. It is a shift in emphasis or a rebalancing away from taking things apart and more towards putting things together. The study and practice of systems analysis provide an insight into what this difference in emphasis might mean. Traditionally, systems analysts, trained in systematic methods of inquiry, spent a great a deal of time critically *analysing* user requirements (Yeates et al., 1994). Despite these painstaking efforts, the history of traditional systems analysis is littered with failed projects and disappointed sponsors. The reasons for this are twofold: the system analysts, on the one hand, were unable to fully understand the requirements of the sponsor and foresee their implications, and the sponsor, on the other, was unable to envisage, in the abstract, the outcomes of the proposed system. The solution to this was to encapsulate their critical thinking in a *constructed* form – the prototype. Nowadays it is common practice for systems analysts to construct prototypes (Chester and Athwall, 2002). Thus, constructing, rather than analysing, has proven itself, at least in this instance, to be an excellent approach to thinking one's way critically through a complex task.

Nardi argued that the field of Human-Computer Interaction has 'largely ignored the study of artefacts', emphasising instead the importance of mental representations (Nardi, 2001).

The critical thinking tradition has also largely focused on the development of mental representations, such as arguments (Bensley, 2010). Facione, for instance, defines critical thinking as 'the ability to properly construct and evaluate *arguments'* (1986: 222) [italics added]. Likewise, the cognitive tool, *Belvedere*, while acknowledging that much of its value lies in the way it encourages collaboration and joint construction of concept maps, its purpose, as described by its authors, is to 'help students learn the nuances of scientific argumentation' (Suthers et al., 1995; cp. Mulnix and Mulnix 2010). Both Bell (1995) and Fisher (2001), as we have seen above, characterise critical thinking almost exclusively in terms of analysis of arguments.

The view proposed here focuses not on verbal argument as a dialectical process that embodies critical thinking within it, but on other kinds of 'recorded' artefact. In the domain of information systems, these artefacts include decision support systems (DSS), websites and many more. MIS students, instead of devising arguments to analyse and critique decision support systems, now construct a DSS model. The artefact itself embodies critical thinking, provides evidence of understanding and, if necessary, a platform for critique. Critical thinking 'is not …. just engaged in situations in which an argument of another person (e.g., in an academic paper) is reviewed' (Moon, 2007: 34). It is not simply about deciding what to believe but also about deciding what to do.

To summarise: The cognitive critical thinking tradition has tended to emphasise analysis, evaluation and construction of evidence-based argument. The view expressed here gives equal emphasis to synthesis and the construction of artefacts in the context of construction as a process of individual and joint attempts at meaning-making.

2.2.3 Taking a Cognitive Approach

Dianne Halpern defined critical thinking as 'the use of those cognitive skills or strategies that increase the probability of a desirable outcome' (1998: 450).

There is broad agreement on what the cognitive skills of critical thinking are. So, for instance, Facione's list contains the following: interpretation, analysis, evaluation, inference, explanation and self-regulation (1990, 2006). Glaser's list – to paraphrase – includes comprehension, interpretation, evaluation, analysis and inference. Similarly, Bloom's cognitive domain lists these skills as remember (knowledge), understand (comprehension), apply (application), analyse (analysis), evaluate (evaluation) and create (synthesis)[1]. Ohlsson's list includes describing, explaining, defining, explicating, predicting, critiquing and arguing (Ohlsson, 1992).

Such classifications, however useful, are not without their difficulties. Looking at the cognitive skills as presented in the lists above it is tempting to think of these as objective, separate components that are well-defined, perhaps even ordered in a hierarchy. However, it is worth remembering, the skills are no more than convenient constructs for labelling how we think. We cannot claim that such constructs have any objective existence. In the natural sciences we can analyse water into its component atoms hydrogen and oxygen, we can separate one from another and we can demonstrate a quantitative relationship – two parts hydrogen to one part oxygen – between the components, such that when that ratio is present water is formed. Between the (postulated) components of critical thinking, however, we can make no such precise distinctions (Furst, 1993).

The definitions of apparently self-evident cognitive skills categories can, also, be problematic. Thus, it is unlikely, as discussed below, that what is described as 'analysis' in one domain is the same as what is described as 'analysis' in another (McPeck, 1981).

Furthermore, the boundaries between the skills are not well-defined. Thus, Bloom draws a line between 'remember' and 'understand'. However, these are not independent

[1] The skills are shown as listed in the revised taxonomy (Anderson et al., 2001), the brackets indicate the corresponding item from the original taxonomy (Bloom, 1956).

entities. For example, our ability to remember affects our understanding and *vice versa* (Chase and Simon, 1973). Similar questions might be raised about other categories such as ‘apply’ and ‘analyse’ or ‘explaining’ and ‘predicting’ (Ohlsson 1995; Neter and Wasserman, 1974: 376-378).

Some skills appear in one list but not in another. ‘Apply’ is an example. In Bloom’s taxonomy ‘Apply’ is a separate skill, but does not appear as a separate skill in either Facione’s or Ohlsson’s lists. In the latter two – we might assume – the skill which Bloom calls ‘Apply’ is present but transcends the other categories. So for instance, it is not possible to engage in the skill which Facione labels ‘interpretation’ without *applying* the skills of interpretation, nor, in the case of Ohlsson, is it possible to engage in critiquing without *applying* the skills of critiquing.

Rather than attempt to resolve the above differences into some overarching framework, this study has settled on Bloom’s revised taxonomy as a way of examining the cognitive aspects of critical thinking. The reasons for this are given below, but first, a note on the taxonomy itself.

Bloom’s taxonomy of the cognitive domain was first published in 1956. The taxonomy, originally one-dimensional, was organised into a hierarchy of six categories: knowledge, understanding, application, analysis, synthesis and evaluation (Bloom, 1956). The taxonomy was extensively revised in 2001. The revised taxonomy is now two-dimensional. The dimensions are cognitive processes and knowledge. The six cognitive processes are now labelled: remember, understand, apply, analyse, evaluate and create. The knowledge dimension consists of four categories: factual, conceptual, procedural and metacognitive knowledge (Anderson et al., 2001).

One frequent criticism of the original taxonomy was that it did not keep pace with changes that had taken place in our understanding of how people learn. Chief among these changes were constructivist approaches to learning and the relatively recent emphasis on metacognition.

The revised taxonomy now addresses both of these issues. A new process – 'create', now assigned the highest position in the taxonomy – honours the importance of construction. As regards metacognition, it is added as a new subcategory of the Knowledge dimension.

In Bloom's original one-dimensional taxonomy categories 2 to 6 represented processes, comprehension, application, analysis, evaluation, and synthesis. However the first category –Knowledge – is both a subject matter category and a process. This anomaly, which was the source of confusion and a target of criticism, has been eliminated from the revised taxonomy by the construction of two dimensions – a Knowledge dimension and a Cognitive Process dimension.

The taxonomy remains vulnerable to the charge that it does not fully take account of social approaches to learning. While that seems true, it might be argued that the taxonomy does not preclude any of these processes from being accomplished either collaboratively or individually.

Despite criticisms, Bloom's taxonomy has some important strengths: The taxonomy is practically useful. Testament of its usefulness has been its widespread appeal to practitioners in the field of teaching and learning – it has been translated into 22 languages (Krathwohl, 2002) and Bloom himself is one of the better-known figures in the field of education. Despite criticisms, few constructs in the field of the learning sciences have proved as durable.

The taxonomy has long been associated with the critical thinking tradition (Moon, 2008). Not only that, the taxonomy has been applied usefully as a vehicle for critical thinking in domains as diverse as critical reading (Surjosuseno and Watts, 1999) and cell biology (Allen and Tanner, 2002).

Bloom's taxonomy also, valuably, calls attention to the fact that not all cognitive skills are of the same order (Bloom, 1956; Anderson et al., 2001; Jonassen and Tessmer, 1996). Skills such as remembering, recognising and describing might be thought of as of a lower order. Skills such as analysing, interpreting, evaluating and creating are considered to be higher order thinking skills. For instance, in the field of information systems the learning outcome 'to be able to open a spreadsheet' might be described as a lower order outcome, since it is a form of doing which can be accomplished, largely, by the recall of a specific key combination. The outcome 'to be able to use a spreadsheet to conduct a cost benefit analysis of competing computer systems' is clearly an outcome of a higher order since it requires not simply 'remembering' but also skills such as applying, analysing, evaluating and creating (Ohlsson, 1995).

Some, while accepting the usefulness of different orders and of distinguishing between certain categories on the basis of their difficulty, questioned the specific hierarchy in which they had been ordered (Paul, 1993). For instance, ‘remember’ comes before (that is, is lower in the hierarchy than) ‘understand’. We know that prior ‘understanding’ facilitates ‘remembering’, that is, understanding comes *before,* not after, remembering. The apparent contradiction may be resolved by arguing that skill categories based on difficulty have become confused with skill categories based on sequence and the fact that one category may be a prior condition for another does not mean that its skill level is necessarily lower or higher than that other category. Nonetheless, it is a reminder that in matters such as ‘thinking’ it is hard to be definitive or categorical.

Irrespective of the precise differences about ordering, it is clear that it is the higher order skills that are indispensable for critical thinking (Jonassen 2003; Patel et al. 2000). In this regard, it is difficult to imagine any non-trivial task – such as those in this study – which does not require some or all of these skills to be engaged (Giardina and Oubenaissa, 2001).

Cognitive accounts also call attention to the difference between surface approaches and deep approaches to learning (Biggs, 1999). Critical thinkers and ‘successful’ students (Ruohoniemi, 2010) are associated with the depth of understanding that results from deep approaches to learning.

Surface approaches are characterised by the acquisition of superficial or disjointed facts, and often amount to no more than learn by rote strategies. Deep approaches are characterised by an attempt to look for meaning, to interrelate concepts in frameworks, to analyse rather than memorise, and to apply knowledge to external contexts based not on surface characteristics, but on deeper, underlying core features. Consider the case of two students, responding to a question on the relationship between motivation theories and information systems (IS). One student can associate the names of the theories and some facts about each with the appropriate theorists. The second student, however, can elaborate the main points, interrelate them, apply them to different contexts, and consider what the motivation-IS relationship implies at several levels such as at the organisation level, the job design level and the interface level (cp. Ellis et al., 2010). The first student might be said to have only a surface understanding of the subject, whereas the understanding of the second is deep (Marton and Saljo, 1976).

Depth of understanding is vital because it orients the thinker to avoid the unforeseen consequences of a superficial understanding of the task, it directs him/her to causes rather than symptoms, it encourages him/her to move systematically from the broad to the narrow and consider the task at progressively deepening levels of detail so as to be in a position to implement a solution (Entwhistle, 1981).

Summing up: The cognitive critical thinking tradition has tended to emphasise individual mental processes – particularly analysing – as well as 'orders' of learning and deep approaches to learning. In attempting a synthesis of cognitive and constructivist approaches to critical thinking in the framework for this study the emphasis falls more on the processes of constructing/'creating' than on analysis.

2.2.4 Taking a Metacognitive Approach

The critical thinking tradition has tended to focus on cognitive skills. Metacognitive skills are now regarded as equally important in all forms of higher order learning and are key to a contemporary framework for critical thinking (Sternberg, 1998; Bransford et al., 2002). Facione refers to critical thinking as 'self-regulatory' and Ennis refers to it as 'reflective'. Richard Paul (1992) describes critical thinking as

> 'the art of thinking about your thinking while you are thinking in order to make your thinking better: more clear, more accurate, or more defensible' (p.11).

Metacognition refers to the knowledge and regulation of our cognitive skills. For instance, constructing a concept map is a cognitive skill. Knowing, however, that concept mapping is an appropriate strategy for thinking one's way critically through a task or for summarising an article is a piece of metacognitive knowledge (Flavell, 1979).

Metacognition is divided into two components: metacognitive knowledge and metacognitive control. Metacognitive knowledge refers to our knowledge and beliefs about our own cognition and cognition generally. Metacognitive control refers to the processes that regulate cognition (Flavell, 1979).

Metacognitive knowledge includes our knowledge and beliefs about the critical thinking task, the critical thinking strategies and ourselves. Task knowledge includes knowledge of the difficulty of the task; strategy knowledge includes knowledge of general and domain specific strategies; and self-knowledge includes an awareness of our preferences, strengths and weakness (Pintrich, 2002; Michalsky et al., 2007; Schraw, 1998).

The processes of metacognitive control monitor and regulate cognition (Manlove, 2009). These processes typically include planning, organising, and controlling. The processes of metacognitive control are also directed at the critical thinking task, the people and the strategy. This might include drawing up an action plan to achieve the task objective and checking progress against it, motivating yourself and others to achieve it and changing strategy in the light of new information (Schoen, 1983).

Metacognitive skills are particularly important where the critical thinking task requires the construction of artefacts. The social process of construction, on the one hand, offers opportunities for the exercise of metacognitive control, while the constructed artefact, on the other, is a focus for the learner's reflection about the task, and provides an opportunity to gain insights into one's own performance and the suitability of the strategies chosen.

In critical thinking, well-developed metacognitive knowledge helps us to become aware of our strengths and weaknesses and well-developed metacognitive control helps us to address our shortcomings and to regulate our approach to tasks.

Summing up: The critical thinking tradition has tended to emphasise the importance of cognitive skills, whereas the view expressed here gives at least equal emphasis to the metacognitive (self-regulatory) skills. This means that the conscious reflection on cognitive skills and processes is considered as being equally important with developing the domain-specific cognitive skills themselves. The process of individual or joint construction that is inherent in the creation of artefacts can act as a powerful way of developing or reinforcing metacognitive aspects of critical thinking.

2.2.5 Taking a Sociocultural Approach

The critical thinking tradition has emphasised the 'individualistic and universal nature of cognitive development' to the 'neglect of the cultural context in the development of cognitive abilities' (Grosser and Lombard, 2008: 1364). A key element of sociocultural theory is that knowledge is distributed and stored throughout the networked components of the community's social system: its members, texts, tools, artefacts, norms, and rules (Wenger, 1998). While conceding that knowledge is partly constructed within the head of the individual knower, sociocultural approaches emphasise the co-construction of knowledge since all of the components of this social system and their affordances are available to support the individual's knowledge construction (Goodyear, 2001). Thus, sociocultural approaches emphasise the collective nature of learning and the social mechanisms that enable it (Dillenbourg, 1999).

The creation of artefacts, made possible by tools, and the social interaction that surrounds their creation – 'reification' and 'participation' – are particularly important in sociocultural theories of learning which seek to understand how members of a community negotiate meaning and learn to construct, maintain and distribute community knowledge (Wenger, 1998: 62-71). According to sociocultural accounts, knowledge is described as tacit or 'encultured' (Blackler, 1995: 1030). Learning to think critically hinges on the extent to which a learner can access and deploy tacit knowledge, which is in turn dependent on the intensity of the learner's participation in the community (Vygotsky, 1978; Engeström, 1987).

Thus, sociocultural approaches call attention to how the social processes of a community may affect thinking. For example, in construction tasks requiring critical thinking, collaborative activities and mechanisms may trigger metacognitive (self-regulatory) knowledge (Dillenbourg, 1999). For instance, the need to explain the task to a peer may activate an awareness of gaps in one's own understanding or the conflicting opinions of peers may cause one to reflect on one's own position (Koschman 2002; Shamir et al., 2009). This is central to both socio-constructivist and constructionist beliefs (Vygotsky, 1978). Moreover, the need to interact with others in order to decide on goals, organise resources and monitor progress may activate self-regulatory control processes.

Meaning-making is an important theme of sociocultural accounts. The process of generating abstract knowledge from concrete experience or of transforming the abstract into the concrete for purposes of testing meaning are twin mechanisms in sociocultural accounts. One way in which learners negotiate meaning is through the application of existing knowledge to meaningful authentic tasks using authentic tools. The other mechanism, participation, helps to shape a sense of identity with other members – learning 'to be' and to 'belong' (Wenger 1998; Yang et al., 2010).

The critical thinking tradition has tended to emphasise the general aspects of knowledge – what Glaser called 'knowledge of the methods of logical inquiry and reasoning' – acquired in traditional instructional settings. Sociocultural accounts of learning tend to emphasise the acquisition of knowledge in situated authentic contexts. In such contexts knowledge, especially domain-specific knowledge, is acquired naturally – on a just-in-time basis (Lave and Wenger, 1991; Brown et al., 1989). Moreover, different skills are often associated with different learning sites (Hill and Plath, 1998).

Such theory characterises knowledge as intimately tied to a particular culture, technology or work activity, 'working knowledge' (Goodyear, 2001: 65; Grosser and Lombard, 2008). Therefore, knowledge or technology that is of use, that 'works' in one situation may not work in another (Benson et al., 2008). For instance, one and the same tool may be enabled or blocked by the presence or absence of certain conditions in the situation or context.

To summarise: Sociocultural approaches call attention to the social process of participation in the community and overlap with constructivist approaches in their emphasis on construction tasks requiring collaborative critical thinking involving a sustained effort after meaning through application of knowledge in authentic situated action. While acknowledging the importance of sociocultural approaches, in this study we do not propose to examine directly the regulatory mechanisms for group learning and how these might interact with tool-based technical mechanisms. The focus is more on how individual critical thinking may be developed through the use of tools in situated, authentic contexts.

2.2.6 Affective and Dispositional Factors

Thus far, we have not paid a great deal of attention to what might be described as the human side of critical thinking. For example, issues such as motivation (Mayer, 1998), learning style (Kolb, 1984) and dispositions (Tishman et al., 1993) are all likely to affect the student's ability to think critically (Antonietti 2009). Dispositions, which can be thought of as the affective or attitudinal component of critical thinking (Tishman and Andrade 1995), have received considerable attention in the critical thinking literature but present the researcher with a variety of problems.

Facione, for instance, lists the following dispositions as important for the critical thinker: [being] Inquisitive, Judicious, Truth seeking, Confident in reasoning, Open-minded, Analytical and Systematic (Facione, 1990: 13, 2006: 9,). According to Tishman, the critical thinker must be (among other things) 'broad and adventurous', 'planful and strategic', 'intellectually careful', 'metacognitive' and have 'intellectual curiosity' (Tishman et al., 1993: 148). There are similarities between the above lists. For example, what Facione calls 'inquisitiveness' roughly corresponds to Tishman's 'curiosity'. However, there are also considerable discrepancies between the lists. It is not immediately obvious how, or to what extent, the majority of the qualities in Facione's list correspond to the qualities in Tishman's list.

Furthermore, the meaning of the dispositions is often vague. Take, as an example, the disposition 'to be broad and adventurous'. What might be described as adventurous in one circumstance might be described as rash or ill-advised in another, that is, the very antithesis of the kind of disposition required for critical thinking. What might be described as a broad treatment of an issue by one individual might be described as superficial by another, that is, diametrically opposed to the deep learning we associate with critical thinkers. Further, one might argue that being ‘intellectually careful’, ‘and being ‘intellectually curious’ look as if they might be contradictory. This suggests a problem with defining dispositions.

Questions also arise about the completeness of the above lists. One could, arguably, add many more dispositions to the lists, such as cognitive flexibility, meticulousness, good memory, discipline and persistence.

What is more, there may well be an unresolved, circular relationship between the disposition and its corresponding behaviour, leading one to wonder if the disposition is the cause or effect of the behaviour. Consider the case of a student who wants to improve his/her critical thinking. What is that student to do if s/he is deficient in one of the essential dispositions, such as the disposition ‘to be metacognitive’? Some possibilities are: S/he might keep a learning log, s/he might mark any passages which s/he does not understand and s/he might circle questions s/he incorrectly answered. In other words, this student acquires the disposition of ‘being metacognitive’ by engaging in metacognitive behaviours or skills (Pintrich, 2002). Indeed, a recent study suggests that enhancement in critical thinking skills reinforces dispositions but the opposite does *not* apply (Yang et al., 2008).

To summarise: Dispositions are difficult to define, there is no common or complete list of key dispositions, and, finally, the relationship between dispositions and behaviours may be a circular one. From the point of view of research, this means that dispositions are difficult to operationalise. Accordingly, the present research focuses on studying constructive, cognitive and metacognitive activities as represented externally in authentic tasks (cp. Jonassen, 1996). The study makes its judgements about critical thinking based on those behaviours associated with these representations rather than on internal dispositions. Thus, it may be that a disposition to approach problems in particular ways represents the acquisition of a compiled (unconscious) critical thinking skill, but whether dispositions can be learned (or taught) directly might usefully be the subject for another research thesis.

2.2.7 Domains of Knowledge

Irrespective of which of the above approaches is taken, there is a reasonably general agreement that knowledge is an important aspect of critical thinking. According to Bloom, the Knowledge-component consists of factual, conceptual, procedural and metacognitive knowledge (Anderson et al., 2001; cp. Blackler 1995; Jonassen and Tessmer, 1996). These distinctions can be helpful in understanding the nature of critical thinking.

Of these knowledge types the cognitive critical thinking tradition has tended to emphasise conceptual knowledge – the kind of knowledge that is more concerned with understanding than with doing (Ohlsson, 1995). Conceptual knowledge consists of formal systems of definitions, concepts, general principles and abstractions. The OSI model in the field of information systems is a good example of conceptual knowledge.

This model is a set of abstract networking concepts, which the MIS student must think his/her way through critically, in order to learn practical networking principles.

Others highlight not so much conceptual as procedural aspects of knowledge – not simply 'knowledge' but 'know how' (Collins et al., 1991). Thus, they are concerned with how facts (factual knowledge), concepts (conceptual knowledge), principles and procedures (procedural knowledge) can be usefully applied in decision-making, construction projects or any critical thinking task.

According to this view, the MIS apprentice learns to think critically about networking not through abstraction but through doing. She checks factual network performance data, she follows procedures manuals for the addition and deletion of users and she applies certain concepts to solve a network configuration problem. In this scenario, at least, critical thinking requires all knowledge types, not just conceptual but factual and procedural as well.

A recurrent issue in the discourse around critical thinking is whether the knowledge associated with it is general or domain-specific. Some claim that critical thinking is a general skill which requires (simply) 'knowledge of the methods of logical inquiry and reasoning' (Glaser, 1941: 5-6). Once learned, it can be applied to any domain – it is a 'mode of thinking- about any subject, content or problem' (Paul et al., 1993) and 'it is based on universal intellectual values that transcend subject matter divisions' (Scriven and Paul, 2003, 2008).

Others argue that critical thinking cannot simply be applied to 'any subject, content or problem', rather that it is domain-specific (Ennis, 1992a, 1992c). Some have seriously questioned the notion that there is a 'single set of actions, skills, propensities or dispositions that can be labelled critical thinking' (Barnett, 1997: 3). One simple way of resolving this issue is to acknowledge that critical thinking has both general and domain-specific components.

What makes the human endowment to think so powerful is that, like language, it has the capacity to transcend domains, situations and contexts. We do not have to invent a new type of thinking for every new task we encounter, just as we do not have to invent a new language for every new context in which we find ourselves. Thus, general critical thinking strategies, applicable to multiple contexts, include disentangling symptoms from causes, analysing facts and drawing conclusions, and developing and evaluating options.

It is also clear, however, that there are many situations in which general critical thinking skills are insufficient. We need domain-specific forms of these skills. 'Analyse', for example, is commonly listed (Bloom, 1956) as a *general* cognitive skill for critical thinking. However the nature of analysing is probably context-dependent. For instance, are we meant to accept that the analysing which is required for a 'critical analysis' of a Shakespearean sonnet is the same kind as that required by the accountancy student for the analysis of a balance sheet? Probably not, since the knowledge required to analyse the sonnet –metres, rhyming and so on – is specific to the domain of poetry, but irrelevant to the domain of accountancy (Mayer, 1998).

Indeed, one might go so far as to say that it is out of domain-specific knowledge rooted in domain-specific experience that meaning arises in large part. The MIS apprentice learns to think critically about networking not through abstraction but through doing, through grappling with the specifics of experience. It is through 'doing', also, that the apprentice comes to understand what networking abstractions *mean* in practice (Collins et al., 1991). Meaning and knowledge result from 'doing' that is grounded in concrete experience.

An abstraction cannot be directly known through the senses. For instance, it is possible to understand, at a conceptual level, abstract ideas about, say, cycling. However it is not until we mount a bicycle and start cycling that we actually 'experience' what cycling *is* and what it *means* to cycle, and, through this experience, our knowledge of cycling is transformed. The transformation it undergoes is from 'knowing about' to simply 'knowing'. At best, conceptual knowledge provides only pointers to the nature of cycling, but by it alone we cannot come to know directly its nature[2].

According to Dewey the essentials required to produce 'good habits of thinking' are:

> 'first that the pupil have a genuine situation of experience – that there be a continuous activity in which he is interested for its own sake; secondly, that a genuine problem develop within this situation as a stimulus to thought; ….that he have opportunity and occasion to test his ideas by application, to make their meaning clear and to discover for himself their validity' (1944: 163).

[2] This is not to suggest that all knowledge must be acquired by personal experience, nor is to undervalue the importance of abstraction, conceptualisation or codification of knowledge that typify teaching and learning in institutional settings. It merely reminds us that much of the knowledge in such settings is often second-hand. Electronic tools, which facilitate the construction of authentic artefacts, offer the possibility of shifting, at least somewhat, the balance between first and second-hand knowledge.

Dewey's view has some similarities with the view expressed here. For instance, the 'good habits of thinking' require exposure to an authentic task in a situated context. Secondly, these habits require the student to be engaged in continuous problem-centered activity; that is, thinking is as much about 'doing' as it is about 'understanding'. If both of these conditions are present the student has the opportunity to apply and test what he knows and to construct his own meaning out of the experience.

To summarise: The critical thinking tradition has tended to place undue weight on the importance of conceptual knowledge, whereas we call attention also to the importance of procedural knowledge. Secondly, the tradition has tended to emphasise that form of general knowledge which transcends domains – such as knowledge of general methods of inquiry, whereas we also emphasise domain-specific knowledge, informed by approaches which recognise the value of applying knowledge in authentic contexts in the pursuit of understanding and the construction of meaning.

2.2.8 An Initial Synthesis: The Proposed Framework

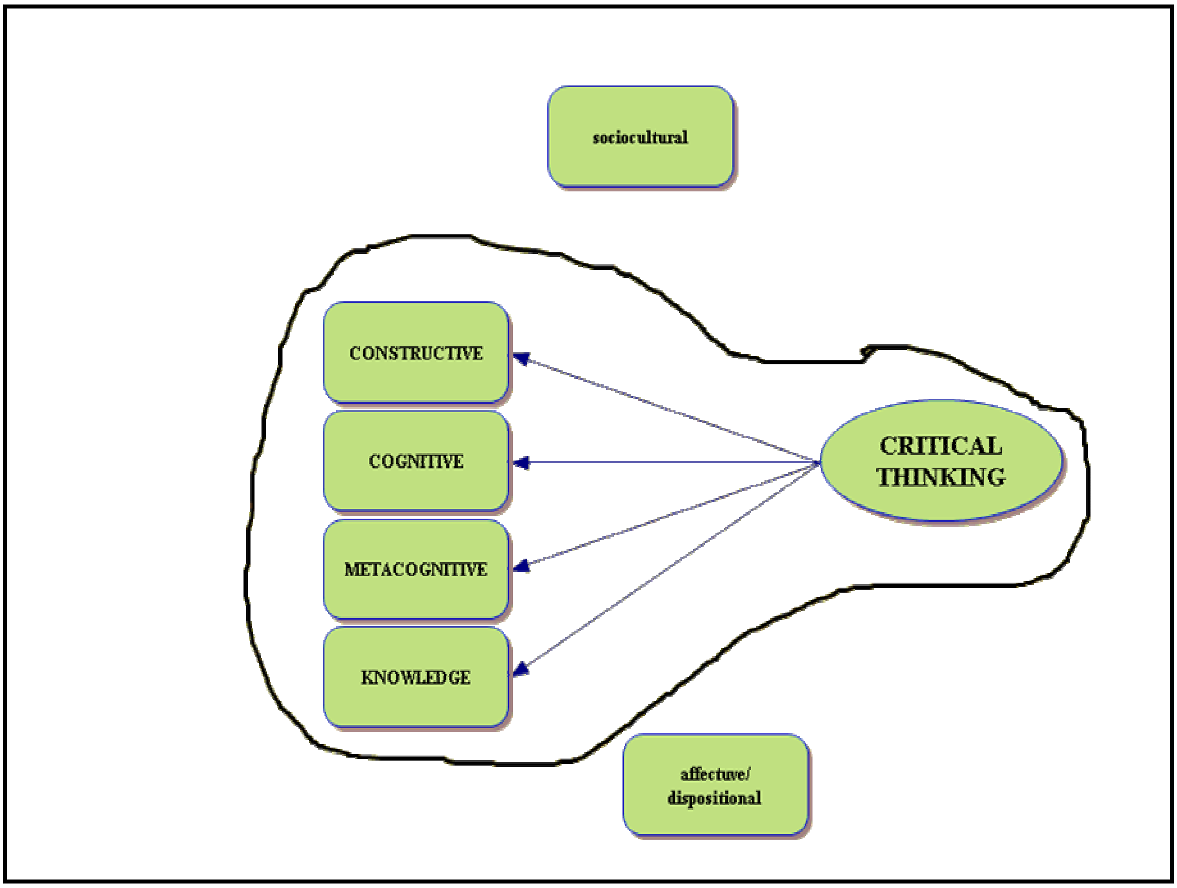
In this section so far we have explored five perspectives on critical thinking (constructive, cognitive, metacognitive, sociocultural and affective), together with the domains of knowledge they may imply and current beliefs about how these domains of knowledge may be learned. In this final subsection a proposed synthesis or framework is offered drawing on all five perspectives. For the reasons explained above and the necessity of keeping the thesis within manageable limits, dispositions as such will not be considered further, instead behaviours which may manifest themselves as good habits of critical thinking are considered. The question of whether such habits are dispositional (a natural tendency of the individual to approach situations in a particular way) or are encultured is a subject left for others to research. This is not to deny the existence or importance of dispositions but, as Sternberg noted about 'abilities', 'we can assess them only through tests that measure developing forms of expertise expressed in a cultural context' (Sternberg, 1998: 137). Similarly, this thesis will only indirectly consider the participation and group-regulatory knowledge and skills necessary to effective collaboration or joint meaning-making processes (whilst noting that these are key components of sociocultural and community of practice perspectives). The value of interaction for learning critical thinking and the importance of developing negotiation of meaning skills for the acceptance of one's ideas is not denied. However, again, to make the thesis manageable these processes are not the main focus of research. Instead the research will concentrate on the knowledge and skills required to construct artefacts using computer-based tools in authentic critical thinking tasks with a focus on the processes involved in the construction of such artefacts and the artefact as a representation of knowledge and critical thinking skills.

The framework for critical thinking presented here can be summarised as follows:

- Critical thinking is inherent in **construction** and the creation of artefacts.
- It requires **cognitive** skills.
- It requires **metacognitive** skills.
- It is based on both **domain-specific** and **general knowledge**.
- It is **not well understood**. It is a human construct.

The framework is represented in the figure below.

Fig. 2.1: The domain of critical thinking of interest in the current research, indicated by the bounded area



2.3 Cognitive Tools and Critical Thinking

In the first section a framework for critical thinking was proposed. This section deals with the relationship between cognitive tools and critical thinking. The section opens with a definition of a tool and provides a discussion of some of the classification issues, focusing the scope of this study on two categories of general purpose, technical, virtual tools, namely knowledge construction (Hypermedia) and modelling tools.

The discussion indicates in broad terms the functions each of these tool types perform and how they can support the constructive, cognitive, metacognitive and knowledge aspects of critical thinking. The section concludes with a summary of the research questions that have emerged from the discussion as a whole.

2.3.1 Definition and Characteristics

The word 'tool' has a multiplicity of meanings. In the field of education, alone – leaving aside the wide variety of colloquial usages – it has been used to describe a system of classification (Bloom's taxonomy), a methodology (soft systems), and a figure of speech (metonymy) (Ahmadian, 2004; Rose, 1997; Flick, 1991)!

This study uses the word tool in a more conventional way, as a 'device' or instrument 'that aids in accomplishing a task' (Merriam Webster). Therefore, a cognitive tool or a 'mindtool' (Jonassen, 1996) is, simply, a device that assists in accomplishing cognitive or critical thinking tasks.

The use of technology as cognitive tools is different from earlier uses in some important respects. Unlike Computer-Aided Instruction (CAI) for instance, the role assigned to the computer is not that of teacher but of a 'mind-extending cognitive tool' (Derry and Lajoie, 1993: 5; Koschmann, 1996) where the learner does not learn *from* but *with* the technology (Jonassen and Carr, 2000: 188-189). The cognitive processing is distributed between the computer and the learner differently: an intelligent partnership where the computer assumes the role of assistant or more capable peer (Reimann, 1995; Lajoie, 1993). Indeed it has been argued that when the learner uses software to create artefacts s/he is in fact assuming the role of teacher, while the computer is assigned the role of pupil (Koschmann, 1996). The cognitive processes of the learner 'are augmented not supplanted' by this use of technology (Hannafin and Land, 1997: 182-3; De Corte, 1995).

Earlier approaches focused on instruction. The focus of cognitive tools is learning. While tools sometimes provide contexts for indirect instruction, more important learning goals are representation and construction (Jonassen and Carr, 2000).

Tightly defined instructional objectives and structure made for rather closed learning environments, even where, as in the case of Intelligent Tutoring Systems (ITS), considerable adaptivity was built into the instructional system (Koschmann, 1996; Hannafin and Land, 1997). In contrast, cognitive tools can be thought of as an essential component of any open-ended learning environment (Alessi and Trollip, 2001) and might even be described as unintelligent tutoring systems (Derry and Lajoie, 1993).

There are several possible classifications of tools. One dimension is that of technical versus psychological. A cognitive tool can be psychological, such as language, or technical, such as a web authoring tool (Saljo, 1995). Another possible dimension for classification is that of virtual versus physical. A cognitive tool can be physical, such as pen or paper, or virtual, such as concept mapping software. A third dimension is that of general versus bespoke. A general purpose cognitive tool, such as word processors, spreadsheets and databases, has a wide range of application (Dalgarno, 2001). A bespoke tool is designed to handle a very specific need such as *Sherlock I* – a tool designed solely to help technicians solve technical problems in a particular context (Lajoie, 1993: 261 *et seq*).

The term 'cognitive tool', as used in this study, is limited to virtual, technical, general purpose cognitive tools, that support the accomplishment of a critical thinking task.

2.3.2 Jonassen's Taxonomy

Within the above general categorisation, it is not easy to further classify cognitive tools (Alessi and Trollip, 2001). The following taxonomy is based on the work of Jonassen. His taxonomy classifies cognitive tools into 'Semantic Organisation, Visualisation, Knowledge Construction and Modelling' tools (Jonassen and Carr, 2000: 168 *et seq*; Jonassen, 2003: 372 *et seq*).

Semantic Organisation tools are any tools, such as databases and concept maps, that facilitate the decomposition and subsequent re-organisation of a domain. Visualisation tools are highly specific, scientific or mathematical tools. Since 'there are no general purpose visualisation tools', these have been excluded from this discussion (Jonassen and Carr, 2000). A Knowledge construction tool is any tool, such as Hypermedia, which supports such construction. A dynamic modelling tool is any tool, such as a spreadsheet, used to construct interactive models, manipulate data, parameters and assumptions and generate results (Lajoie, 1993; Alessi and Trollip, 2001).

This study focuses only on Knowledge Construction Tools and Modelling Tools. Within each of these categories the study focuses on Hypermedia as one instance of a Knowledge Construction tool and the spreadsheet as one instance of a Modelling Tool. The brief discussion below provides a broad indication of how such tools support the constructive, cognitive, metacognitive and knowledge aspects of critical thinking outlined in the framework above.

2.3.3 The Critical Thinking Framework and the Functions of Cognitive Tools

Knowledge Construction (Hypermedia) Tools

Central to constructivism is the belief that learners best articulate their knowledge by fashioning constructs (Jonassen, 2003). A Knowledge construction tool (Jonassen and Carr, 2000) is any technology which supports such construction – a key element of the proposed framework for critical thinking. A very wide range of tools can be included in this category since most software allows some form of construction. Jonassen includes conversational and collaborative tools, presentation tools, web development software, web-based video and Hypermedia.

Web-authoring, presentation and hypermedia have all been grouped here under the label ‘Hypermedia’ since they (1) are all treated, in this context, as knowledge creation tools

(2) use *hyper*text in some form (3) build interconnections via *hyper*links and (4) generally use multimedia (Alessi and Trollip, 2001).

Thus Hypermedia, as used here, is any dynamic, navigable, knowledge construction multimedia tool. The knowledge is represented as nodes (e.g., pages) which are interconnected by dynamic hyperlinks.

Generally speaking, knowledge construction (Hypermedia) tools are hypothesised to facilitate critical thinking as follows: Such tools are by definition **constructive** – the technical corollary of the assumptions that (1) each individual constructs his own **knowledge** (Dalgarno, 2001) and that (2) one learns more by constructing than by listening or reading (Jonassen, 2003). Construction of Hypermedia also stimulates the **cognitive** and **metacognitive** processes (Lajoie, 1993). For instance, Hypermedia facilitates cognitive activities such as analysis and synthesis, since to decide on the Hypermedia content the learner must first decompose the domain, and to create the Hypermedia artefact s/he must later synthesise the Hypermedia components in some way, using mechanisms such as hyperlinks. Hypermedia facilitates metacognitive activities since all such forms of construction require regulation. In brief, Hypermedia's 'richer representation' can cultivate a 'more rounded understanding' and help learners think more creatively and critically (Munro, 2000).

Modelling Tools

Generally speaking, modelling tools are hypothesised to facilitate critical thinking as follows: a spreadsheet, like any other tool that is used to build or create even the simplest of models, supports the **constructive** aspects of critical thinking. In the case of any non-trivial task, spreadsheets also require users to deploy their conceptual **knowledge** (Jonassen and Carr, 2000; Bransford et al., 2002). Spreadsheets also support the **cognitive** aspect of critical thinking since users must 'constrain the problem', decide on a goal, analyse critical factors and distinguish between data, assumptions and constraints (Lajoie, 1993: 268). In addition, spreadsheets facilitate hypothesis generation and 'causal reasoning' (Jonassen, 2003) since they are designed to handle tasks such as what-if analysis. Spreadsheets also promote the **metacognitive** aspect of critical thinking, in that the interactivity of modelling tools facilitate feedback, by means of mechanisms such as error messages (Alessi and Trollip, 2001).

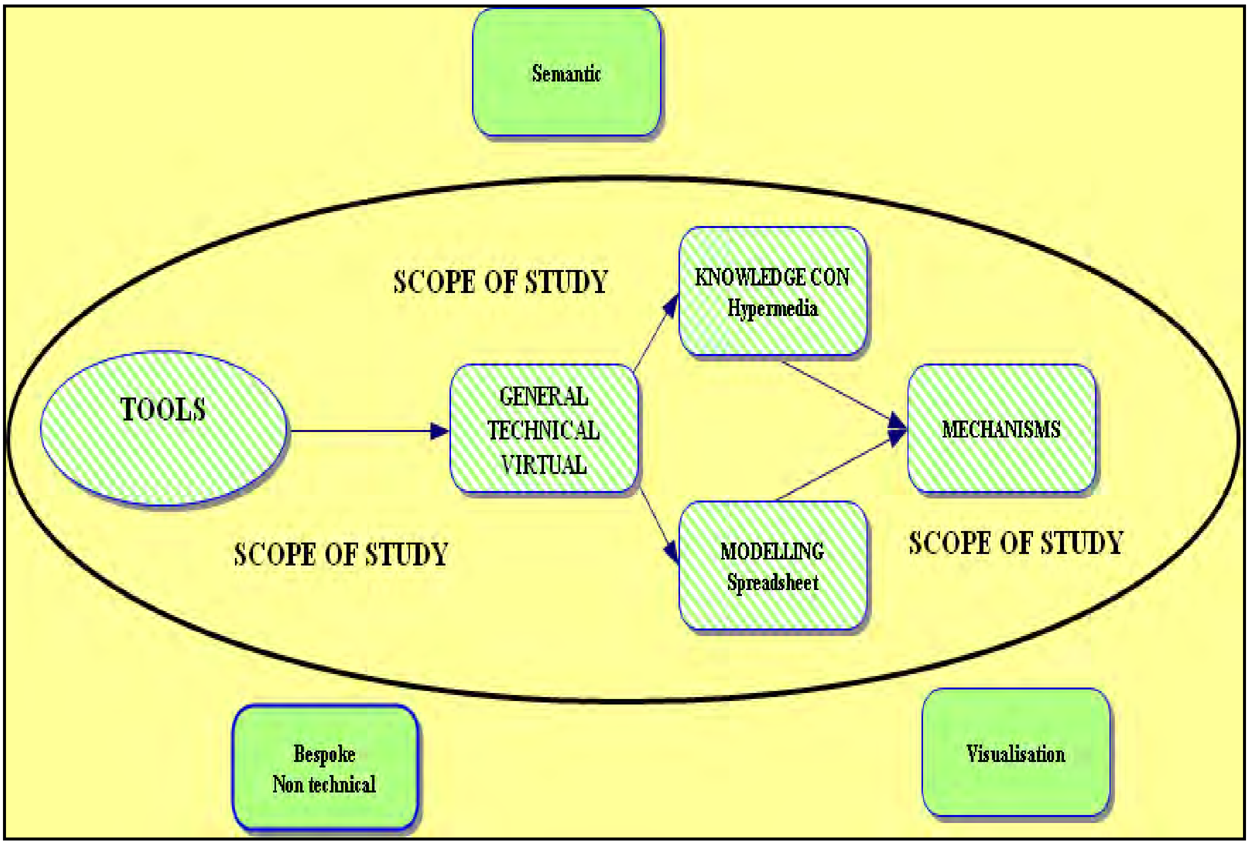
In general terms, then, cognitive tools 'enable learners to represent what they know' by helping them organise, construct, model and research knowledge (Jonassen, 2003: 372; Jonassen and Carr, 2000). Cognitive tools allow learners to engage in forms of 'advanced thinking' (Bransford et al., 2002: 214) and 'useful activity' (Brown et al., 1989: 34) which would not be possible without them. They scaffold different kinds of knowledge representation by providing 'structural, logical, causal, systemic, or visuospatial formalisms' (Jonassen and Carr, 2000: 167). Finally, they scaffold critical thinking by supporting the constructive, cognitive and metacognitive elements of the critical thinking framework.

2.3.4 Sociocultural Mechanisms that Promote Tool Use

Sociocultural accounts foreground the use of tools. The MIS apprentice tackles problems by using diagnostic tools, checking logs and policies, often interacting with users and peers. Thus sociocultural accounts look on tools as social objects whose modes of operation have been developed socially and which also promote interactions between participants (Verenikina, 1998). Accordingly, the learning about, and the deploying of, what have been called 'social mindtools' (Nuutinen et al., 2010), in line with the community's culture, tradition and context is a key issue in such accounts.

Tools, as the tacit embodiment of the culture, also serve to perpetuate the community practices. The layout of the blacksmith's forge is a reflection of the farrier's tasks and the tools at his disposal, and as well as a way of working, a practice. Finally, sociocultural accounts distinguish between psychological and technical tools – a useful reminder that tools shape both the material and cognitive domain (Vygotsky, 1978).

Fig. 2.2: The domain of 'cognitive tools' of interest in the current research represented as contained *within* the elliptical bounded area in the figure below



Summarising, in this section we have offered a definition of cognitive tools, discussed some classification issues, indicated how cognitive tools differ from other uses of technology and how they can *generally* support the constructive, cognitive, metacognitive and knowledge aspects of critical thinking.

2.4 Research Focus

2.4.1 Scope of the Thesis

Learning to think critically requires the learner to build on prior knowledge using existing cognitive and metacognitive processes to generate new frameworks to plan, action and, very importantly, reflect on performance. Learning to think critically is also a social and affective activity that is influenced by our interactions and feelings. While the importance of social and affective approaches to learning are acknowledged, they are not included in the scope of the thesis and they are only considered indirectly.

Much of the previous research described in this chapter is conducted at a fairly general level and its assertions are not always based on empirical evidence. While suggesting that tools generally can enable critical thinking, previous research has not, for instance, considered in any detail the mechanisms by which particular tools enable particular critical thinking effects. This research, set in an authentic context, aims to fill that gap, at least partially. Its purpose is to provide a more detailed understanding of how cognitive tools, at mechanism level, on the one hand, reinforce and enable critical thinking strengths, or on the other, how they help to expose critical thinking weaknesses.

In the light of the above discussion, the term ‘cognitive tools’, as used in this study, is limited to virtual, technical, general purpose authentic cognitive tools. Within this general scope the tools are further restricted to Knowledge construction (Hypermedia) and Modelling tools. Excluded from the study are all other forms of tools, especially physical, psychological tools and bespoke tools. This scoping is summarised in the table below.

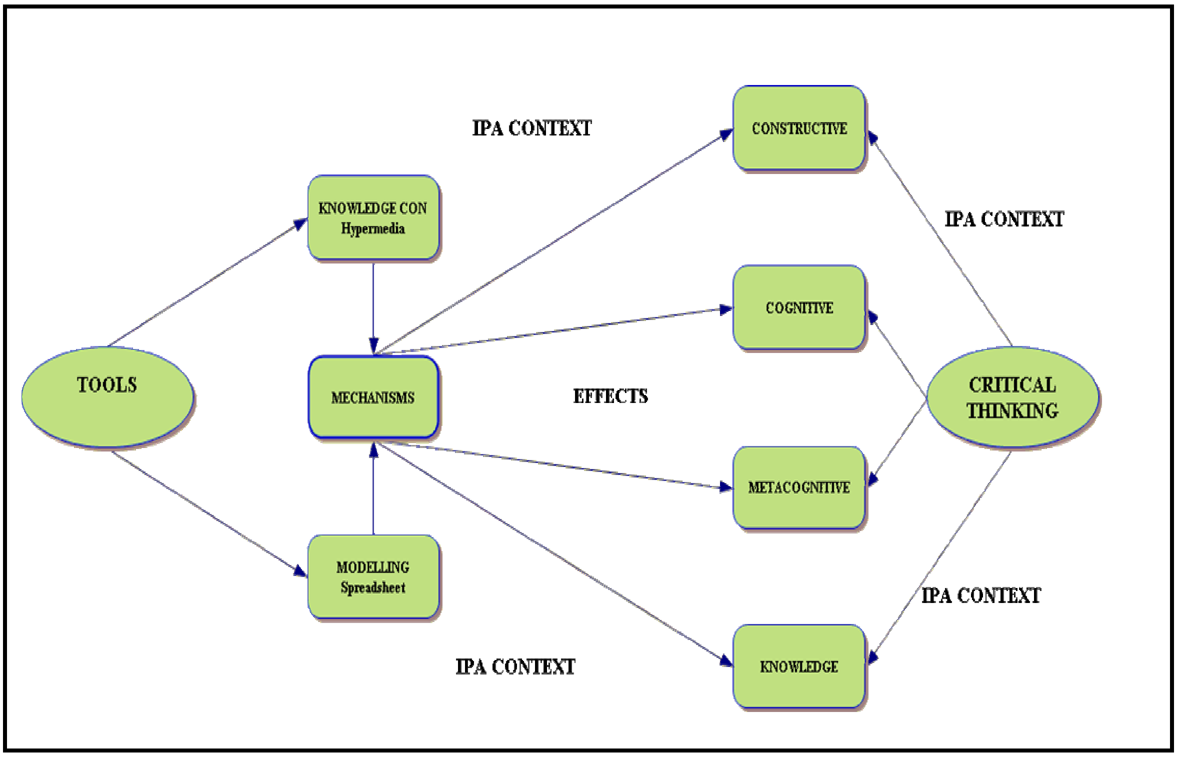
Table 2.1: Final scoping of the current research including critical thinking, cognitive tools and IPA context

IN	**OUT**
Constructive, cognitive, metacognitive, knowledge aspects of Critical Thinking	The affective and group-regulatory aspects of Critical Thinking (the detailed study of socio-cultural, interactive and participatory mechanisms of managing dialectic and collaborative activity)
Artefacts (the skills, processes and beliefs embodied in the construction of project artefacts and what these tell us about critical thinking)	Arguments (see above)
General purpose, virtual, technical tools	Bespoke physical or psychological
Authentic tools	Non-authentic
Knowledge construction (Hypermedia) Modelling tools (spreadsheets)	Other tool categories, e.g., Visualisation, Semantic Organisation
IPA context	Other general contexts

Finally, the enquiry is rooted in the IPA context and this is reflected in the research scope. The research does not set out, as a primary objective, to make generalisable assertions about any other contexts (It is, of course, hoped that the research will be of value in contexts similar to the IPA). Since IPA tutors are primarily interested in ‘what works and what doesn’t’ the main focus of the research will be to suggest possible ‘answers’, however provisional, to this question. An important part of the research will be the production of guidelines, which IPA tutor-designers can incorporate as ‘useful ideas’ into their own teaching practice (MacLure, 2003). The figure below is a graphical representation of the scope.

2.4.2 Framework for the Study

Fig. 2.3: The Research Scope: The domain of critical thinking and cognitive tools of interest in the current research. IPA context shown.



The above framework for the study has been translated into the following research questions.

2.4.3 Research Questions

Table 2.2: Summary of Research Object, Framework and questions	
Theoretical framework	**Research Questions**
A specific framework for critical thinking consisting of the following aspects: Constructive Cognitive Metacognitive Knowledge and A Classification of Tools (esp. Hypermedia and Modelling)	**1. Strengths and weaknesses in critical thinking** What strengths or weaknesses in the constructive, cognitive, metacognitive and knowledge aspects of critical thinking does the use of cognitive tools make visible? Do any patterns emerge that are related to category of tool or type of task? **2. Students' perceptions of strengths and weaknesses in critical thinking** What are the perceptions of students in relation to the strengths and weaknesses of their critical thinking performance? What is the relationship between these perceptions and the findings for Research Question 1? **3. Mechanisms and conditions** By what mechanisms, and under what conditions might tool use enable/facilitate critical thinking? **4. Implications for teaching** What are the implications for teaching and learning in the IPA context? How might the findings be translated to be useful to IPA tutors?

2.5 Chapter Summary

This chapter has drawn on multiple approaches to critical thinking to present a framework which characterises critical thinking as constructive, cognitive, metacognitive and knowledge-based. Combining this with key ideas about how cognitive tools might enable critical thinking and focusing on a gap in the field of knowledge, the chapter refines the research scope and concludes with the set of four research questions immediately above.

2.6 Reflection

Skias onar anthropos

Man, the dream of a shadow

Pindar

In this chapter I have presented a framework for critical thinking. I am happy with that. However, it is possible to look at the issues raised from quite a different point of view. We need to bear in mind that the research object, critical thinking, is simply a human construct. It does not ‘really’ exist, but it can be convenient to ‘think’ that it does. Further, we need to remember that the framework too is no more than a convenient way for thinking about critical thinking – not so much a framework for how we think (critically) but a framework for *how we think* we think!

Other questions now arise: to what extent, for instance, can critical thinking be distinguished from other forms of thinking such as creative thinking? If there are ‘real’ differences between ‘creative’ and critical thinking, is one more valuable than the other?

We need to admit that we do not know exactly what thinking is or what a thought is. For instance, is thought energy? Is it a mind form? A brain-form? Nor do we know exactly the relationship between a thought and a feeling. Thus it is worth reflecting that in any research into critical thinking, the very foundations of thinking on which it is based are laid in the shadows, invisible, deep below the surface.

Maybe, too – I can't help feeling – in the western tradition thinking has been overvalued. Thinking is only one way, a rather limited way, of experiencing and making sense of the world. Can we really know ourselves and the world through thinking alone? It seems to me that *being*, not thinking – being in the world, being ourselves, being fully aware, truly knowing ourselves – is an altogether worthier pursuit than critical thinking, although critical thinking may be a partial means to that end. Being encompasses such thinking, though thinking is only a relatively small part of being. Meditation, since it is a technique designed to quieten thought and to bring stillness, might be considered as the very antithesis of thinking. According to eastern tradition, it is through meditation we come into contact with being and 'enlightenment'– it is enlightenment that produces clarity of thinking, not the other way around.

The major implication of this reflection for any research into critical thinking is the need to remember that critical thinking is a construct, and that much of the foundations upon which critical thinking discourse is based is veiled in ignorance. I have tried to be aware of this at all stages in the research in evaluating the claims of others or in presenting my own.

CHAPTER 3: RESEARCH DESIGN AND METHODS

3.1 Introduction and Purpose

The purpose of this chapter is to develop, justify and present a research design, consistent with the theoretical framework, which can address the research questions presented in the last chapter.

Following a preliminary review of the framework, research questions and ontological issues, the chapter falls into three main divisions. The first deals with the overall design, the second describes and justifies the chosen research methods whilst the third section reflects on methodology and trustworthiness. The first section discusses but discards fixed designs; the second describes two data collection methods, an authentic critical thinking task, COGITASK and an OnLine Discussion forum, OLD, which respectively generate quantitative and qualitative data on student performance and perceptions of it. The third section justifies the choice of a mixed method case study design and discusses issues of trustworthiness.

3.2 Research Purpose, Questions and Related Issues

3.2.1 Purpose and Questions

The study of cognitive tools and critical thinking that is proposed here is envisaged as being more exploratory than explanatory. It does not seek to establish and quantify causal relationships between cognitive tool use and critical thinking performance. While the study, rooted in the IPA context, does not aim to make generalisable assertions about any other contexts, nonetheless, it is hoped that the study will be of interest to others, especially those in contexts similar to the IPA.

The research, proposed here, aims to enrich the general discourse on tool-enabled critical thinking by (1) providing the basis for a draft set of original, generalisable, research-based guidelines for tutors on the use of cognitive tools to enable critical thinking. These guidelines can be thought of as a way of bridging the gap between the complexity of the research context and the requirements of daily teaching practice. (2) providing new empirical data on how tools facilitate certain critical thinking effects, especially in relation to general purpose Hypermedia and Modelling tools.

The research questions and the theoretical framework (characterising critical thinking as constructive, cognitive, metacognitive and knowledge-based) were presented at the end of Chapter 2. The aim of the discussion in this chapter is to match the research questions, purpose and framework to the selection of an appropriate research design and a set of data collection methods.

3.2.2 Ontological Issues and Epistemological Implications

The study of critical thinking and cognitive tools confronts the researcher with difficult ontological and epistemological issues. These issues are summarised below.

- No universal consensus exists on the nature of thinking, including critical thinking – it is not well understood. Accordingly, the research needs to develop some ‘working definition’ of critical thinking before it can proceed. The critical thinking framework, developed in the previous chapter, serves as such a working definition.

- Since thinking is not well understood, any categorisation of thinking such as Jonassen's (1996) classification of thinking into critical thinking, creative thinking and complex thinking is also problematic.
- Thinking is not a directly observable phenomenon. Therefore, the researcher needs to use indirect indicators which provide evidence of critical thinking. There is, however, no standard list of such indicators/cognitive skills: the research must either select *one* list or attempt to synthesise competing lists (e.g., Anderson et al., 2001; Bloom, 1956; Ohlsson 1995; Jonassen and Tessmer, 1996). Bloom's revised taxonomy, despite its difficulties, has been largely adopted for this research.
- Critical thinking is constructive and tools are used to construct artefacts. Since the artefact reflects the appropriateness of tool choice, the user's conceptual understanding of the task in hand and their procedural or technical knowledge in the use of the tool, artefacts should be a most important focus of any research into the use of cognitive tools for critical thinking.
- The creation of any tool-based artefact is surrounded by discourse which should also be an important source of research data especially into the metacognitive aspects of critical thinking
- Tools are ontologically curious: they are defined not so much by their nature as by their use. Therefore, research must observe how they are used in practice and point to enabling contexts or conditions of use.

- Given that tools are not defined by their nature but by their use, categorisation, not surprisingly, is problematic. This research uses Jonassen's categorisation of tools into Knowledge Construction, Modelling, Semantic, and Visualisation tools. However it is important to remember that this categorisation is not water-tight, and therefore any findings should be interpreted with caution.
- Nonetheless, it is possible to make reasonable distinctions between different tool types, such as Knowledge Construction (Hypermedia) and Modelling tools. A question of interest to this research is the extent to which different tool types might enable different critical thinking effects.

3.3 Research Design

This section discusses the overall research design. This includes a discussion of possible designs and a justification of the choice of a flexible research design, specifically, a multiple case study.

In any study into critical thinking the researcher, as noted above, is confronted immediately with the problem of how to collect data on a phenomenon, namely 'thinking', that is not directly observable. What methods can the researcher employ? Or, how do we make 'thinking visible' (Collins et al., 1991: *passim*)?

The answer that is proposed here is twofold:

1. Student-subjects construct an artefact from which the researcher deduces their thinking.
2. Student subjects talk about the construction of that artefact, in other words, they record their *thoughts.*

The implications of and justifications for this approach are discussed in the remainder of this section.

3.3.1 Matching Questions and Purpose to Possible Designs: Choosing a Fixed or Flexible Design Strategy[3]

The study of cognition, cognitive tools and critical thinking has a long association with psychology, the positivist tradition of enquiry, and hence fixed research design (Gilstrap and Dupree, 2008; Moreno, 2006; Suthers et al., 1995; Ferry et al., 1998). For that reason alone it is worth examining the extent to which a fixed experimental design might be appropriate for the study under consideration here.

A typical fixed (quasi) experimental design for this study might include (cp. Moreno, 2006: *passim*; Yang et al., 2008; Shamir et al., 2009):

(1) the formulation of measurable hypotheses (2) division of subjects into treatment and control groups (3) to which members are randomly assigned (4) and given pre- and

[3] Research Design terminology varies from text to text. For instance, Robson classifies Research Design Strategy into flexible and fixed strategies, while Bryman classifies it into Quantitative and Qualitative strategies (Robson, 2002: 95-199; Bryman, 2001: 28-60; cp. Gomm et al., 2000). The terminology adopted in this chapter follows Robson.

post- tool-based critical thinking tests (5) which will be subsequently measured and analysed against the hypotheses using classical statistical methods.

However, such a design creates problems. Firstly, it will be difficult to state hypotheses about thinking that are well-defined and easily measured, such as are normally required in a fixed design. Secondly, the division of students into treatment and control groups would, in the case of IPA, be neither feasible nor acceptable. Similarly, randomisation would be impractical in the authentic setting of IPA classrooms since students enrol in accredited programs of their own volition; they are not, and cannot be, randomly assigned to them.

The design is also likely to be vulnerable to multiple threats to internal validity. For instance, critical thinking takes time to develop. Differences in critical thinking performance, measured over time, may be due not to any tool-enabled effect but to the natural development of the student – the maturation threat. Similar arguments can be made in relation to instrumentation and sensitisation threats (Campbell and Stanley, 1963). Consequently, a fixed research design strategy has been discounted for the research proposed here.

It follows, therefore, that a flexible strategy of some kind needs to be adopted. The case study suggests itself as an appropriate and natural strategy type for this research for the reasons outlined below.

Yin defines a case study as an enquiry into

> 'a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident' (Yin, 1994: 13).

The study under discussion here satisfies all the main points of Yin's definition. Critical thinking and virtual cognitive tools are both contemporary phenomena. The study is rooted in the particular, that is to say, the real-life, context of the IPA. Further, that context, far from being something to be controlled, isolated or removed from the study – as in fixed designs – is indeed partly the focus of the study. Unlike the fixed design, the case study strategy type seeks to answer exploratory 'how' and 'why' questions of the kind that is of interest in this inquiry, rather than explanatory 'what or 'how much' questions. All of the above suggests that the case study is well matched to the requirements of this research (Gomm et al., 2000).

Choosing the type of Case study

Given that we have argued that a case study is the appropriate strategy type for the proposed research, what type of case study should be used?

The single case study design, whether critical, unique, or longitudinal (Yin, 1994), has been discounted since it was judged that the single study design could not answer all of the research questions.

The design proposed here is a multiple case study (Yin, 1994, cp. Kozma and Anderson, 2002). The study is divided into four cases, classified by tool category. There are two Hypermedia and two Modelling cases. The students, divided into teams, complete each of the cases. The cases are broadly representative of the range of tasks in which MIS students might be expected to engage in the IS world of work .

Each case consists of an authentic tool-based critical thinking task referred to as a COGITASK, and an OnLine Discussion, OLD. The critical thinking task generates an electronic artefact such as a website or a spreadsheet model (cp McFarlane et al., 2000). OLD generates text-based perceptual data. Both COGITASK and OLD provide data on student strengths and weaknesses – the main focus of Research Questions 1 and 2.

The within category cases, that is, the two cases within the Hypermedia category or the two cases within the Modelling category, serve as literal replications. This means they have been selected to predict similar results – to answer questions about similarities within tool categories. The between category cases serve as theoretical replications, selected to predict contrasting results but for predictable reasons – to answer questions about the differences between tool categories (Yin, 1994).

Thus, the multiple case study approach, incorporating authentic tool-based tasks and online discussions, is designed to address the key research questions relating to student strengths and weaknesses in tool-enabled critical thinking as well as student perceptions of their strengths and weaknesses. The design is summarised in the table below.

Table 3.1: Research Design, showing a total of four cases, classified by tool category (two hypermedia and two modelling). Each case is taken by five teams.

Tool Category Name	Case Name (COGITASK)	Description	No of cases	No of teams per case
Hypermedia	Customer Web	Students are required to design a Customer- oriented website for one of their organisations. This includes analysing the factors that influence the design, designing the site and developing a prototype.	1	5
	Online Tutorial	Students are required to design an online tutorial which will explain one of the key topics of their course. This involves selecting the topic, deciding on the key issues in the topic, designing the tutorial, assembling assets and developing the online tutorial.	1	5
	Sub Total		**2**	
Modelling	BPR	Students are required to re-engineer a Business Process critical to one of their organisations. This involves analysing the old process(es) and designing and modelling the new process.	1	5
	EIS	Students are required to design an Executive Information System for one of their organisations. This includes deciding on the overall structure of the EIS, what information, it should contain and developing a prototype EIS which will provide and present this information.	1	5
	Subtotal		**2**	
Total			**4**	

3.4 Description of the Data Collection Methods

The previous section dealt with the overall research design issues. This section focuses on *methods*, specifically data collection methods. The section describes two methods – COGITASK and OLD – and justifies their choice.

For Research Question 1 the COGITASK, an authentic task, will provide quantitative data on critical thinking performance. For Research Question 2 the OLD, an online discussion, which records each student's perceptions of the COGITASK, will provide text-based qualitative data on perceptions of their performance (Ellis et al., 2005; McFarlane et al., 2000: *op. cit*). Quantitative and qualitative methods, such as exploratory data analysis and (textual) content analysis, are used to analyse the data (Clegg et al., 2000: 137; Kozma and Anderson, 2002: Erickson and Nosanchuk, 1988). A full discussion of analytical methods is provided in the two subsequent chapters.

The choice of the COGITASK method has been partly influenced by socio-constructivist accounts which describe how people, engaged on authentic tasks, learn through the construction of artefacts in authentic settings using the tools of the trade (Wenger, 1998; Wenger et al., 2005). In this way, the effectiveness of their thinking, otherwise latent and hard to judge, is made visible through the artefact and can be evaluated by practice constituted criteria (Usher, 1996: 26-27). Since the artefact creation process invariably includes discourse of some kind, this offers the researcher the opportunity to analyse not only the artefact but the discourse around it (Research Question 2). The choice of the OLD method has been partly influenced by cognitive conceptions of learning since OLD is more concerned with knowledge than competence, more concerned with understanding than with doing. Thus the methods are grounded in the two main paradigms – the constructive and the cognitive – which have dominated theoretical ideas about learning in the last 40 years (Koschmann, 1996).

The use of such methods is also well aligned with the general approach to instruction in the IPA's accredited programs. These are typified by short workshops where participants work on problems and 'do things', rather than simply listen to lectures.

3.4.1 COGITASK

The COGITASK method is, essentially, an authentic 'design and make' (Johnsey, 2000), critical thinking task in which student-subject teams construct an artefact using authentic general purpose Hypermedia and Modelling tools. It requires not simply a passive understanding but an active demonstration of competence (Coleman et al., 2002). (A summary description of each COGITASK appears in the table above and a detailed description is available at Appendix 3.1).The task is completed by MIS students in small teams of two to four.

The purpose of the COGITASK method is to collect empirical data on critical thinking *performance*. The method generates evidence in the form of an artefact. From the artefact, the researcher derives quantitative data. Performance is scored against a marking scheme (Heron, 2006). The method is *not* designed to directly collect data about the process, collaborative or group-regulatory mechanisms (Wiedenbeck et al., 2000; Clegg, 2000). The COGITASK is administered in the natural setting of the classroom at the end of each of the four modules of the MIS course. The task is of 4-5 hours duration and forms a natural part of the teaching and learning of the MIS program.

The psychometric test was considered as an alternative method for collecting data on critical thinking performance but was discounted for the following reasons. Psychometric tests are not authentic tasks and do not, typically, provide measures of domain specific critical thinking. The COGITASKs, such as the design of a website or an EIS model, are tasks *authentic* to the domain of information systems – 'real-life' tasks which any IT professional might be required to complete.

The COGITASK is a *higher order critical thinking* task. That is to say, each COGITASK requires the learners to engage in higher order cognitive skills. For instance, the customer website design task requires students, to use the language of Bloom, to understand theories of IT customer service, to apply their knowledge of web technologies to the design of a website, to analyse their customers, to create a functioning website and to evaluate their performance (Anderson et al., 2001).

The COGITASK, unlike the psychometric test, is a *tool-based task*: it cannot be completed without the use of an authentic, cognitive tool. This is important since the study is concerned with the relationship between tools and thinking.

Thus, the COGITASK is an authentic, critical thinking task which requires the learner to use virtual cognitive tools. Since the overall aim of the study is the relationship between critical thinking and virtual cognitive tools the selection of such tasks as the principal method of investigation has strong claims to construct validity – a subject discussed more fully below.

3.4.2 OLD

On completion of each COGITASK, each individual student-subject records in an OnLine Discussion forum (OLD) a narrative account of their impressions of what they have learned as a result of completing the COGITASK (cp. Perkins and Murphy, 2006). OLD is completed by the use of a specific virtual cognitive tool, called a discussion tool (See Appendix 3.2).

OLD, which orients students toward reflection, forms a natural part of the learning, since MIS students are asked to contribute to some 20 such discussion tasks in other parts of their course (Greenlaw and DeLoach, 2003).

The purpose of the OLD task is to supply evidence, in the form of 'subjective' data, about students' *perceptions* of their critical thinking performance (Abrams, 2005). The empirical data provides insights into how the use of virtual cognitive tools can facilitate certain critical thinking effects, especially in relation to the metacognitive aspects of the critical thinking framework (McLoughlin and Mynard, 2008; Perkins and Murphy, 2006). OLD is administered in the classroom at the end of each module, immediately after the completion of the COGITASK. It takes a student about 30 minutes to compose and upload a contribution.

OLD has been selected in preference to alternative methods, such as the questionnaire, for capturing data about students' perceptions of their critical thinking performance (Yang et al., 2008). The reasons are described below.

The OLD method requires student-subjects to actively *construct* their own responses and externalise their thinking, in writing and 'in public', in such a way as to encourage more deliberative reflection (Greenlaw and DeLoach, 2003). Such reflection is obviously essential to the metacognitive aspect of critical thinking (Abrams, 2005). The questionnaire, with its tick boxes and standard responses, is a more passive instrument.

OLD also provides data which, in its own right, can be analysed for its critical thinking content. (Guiller et al., 2008: Greenlaw and DeLoach, 2003). The questionnaire cannot provide such additional evidence of a student's critical thinking ability.

OLD provides rich, subject-centered data (Kozma and Anderson, 2002). Each subject defines, in his/her own terms, what s/he perceives as important. The questionnaire, in contrast, may tend to overly reflect the researcher's agenda.

(This is not to deny that psychometric tests and questionnaires have important benefits. They structure data collection and generate data that are easier to analyse than the data generated by the COGITASK and OLD methods).

3.4.3 Complementarity of COGITASK and OLD Methods

The COGITASK and OLD methods complement each other well (McFarlane et al., 2000). COGITASK provides quantitative data on critical thinking performance, OLD provides qualitative data on perceptions of that performance (Ellis et al., 2005); COGITASK and OLD when taken together provide comprehensive coverage of the critical thinking framework: COGITASK provides data on the constructive and cognitive aspects of the framework and OLD provides data on the metacognitive aspects (Abrams, 2005); both provide data on the knowledge aspect. The COGITASK method is the basis for the reflections in the OLD method but the OLD method provides useful feedback as to the efficacy of the COGITASK method.

All of the above suggests that the two principal methods, COGITASK and OLD, are sufficient to answer the research questions.

To summarise: this section has described two complementary methods of data collection, referred to as COGITASK and OLD. The first is an authentic critical thinking task designed to capture data on critical thinking performance; the second is an online discussion designed to capture data on students' perceptions of their performance.

3.5 Choice of Methodology

This section discusses some methodological issues. It justifies the mixed method approach and discusses in detail the trustworthiness of the research.

3.5.1 A Mixed Method Approach

The approach chosen for this case study is a mixed method one. ‘Mixed method’ reflects the selection of both quantitative and qualitative approaches to data presentation and analysis (McFarlane et al., 2000). For example, quantitative methods are applied to the COGITASK data. Unlike a textbook problem this task is open-ended, complex and messy without any one ‘right answer’, amenable to some quantification (e.g., overall grading) but in the full knowledge that such data are often based on underpinning subjective judgements. Qualitative approaches are applied to the perceptual data from online discussions (OLD). The approach (1) captures the students’ perceptions of their strengths and weaknesses and how they fit with the tutor’s (they rate their performance similarly) and (2) enables, by means of its textual data, the researcher to see the basis for judgements – ‘how’ and ‘why’ students think as they do and their own subjective judgements concerning their performance and their use of tools.

Mixed methods has been defined as

> ‘the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study’ (Johnson and Onwuegbuzie, 2004: 17).

The use of mixed methods can be justified in that the research questions dictate that quantitative data be gathered on critical thinking performance and qualitative data on students’ perceptions of their performance. The methods are complementary. More generally, the decision in many cases is not whether mixed methods should be used but in what proportion. Ann Brown had this to say:

> 'Increasingly, I find that in the interest of converging operations, and because of the multifaceted nature of my data base, I prefer a mixed approach, suiting the method to the particular data. I mix and match qualitative and quantitative methodologies in order to describe the phenomena, a mixture that is becoming commonplace' (Brown, 1992: 156).

3.5.2 Trustworthiness in Design

This sub-section examines the extent to which the design satisfies the requirements for validity –construct, internal and external – and for reliability (Yin, 1994; Robson, 2002; Bryman, 2001).

A test can be said to have construct validity if it measures what it claims to measure (Yin, 1994: 35-36, Robson, 2002: 93). This implies that the study (1) must present a clear definition or description of the construct to be measured, in this case, critical thinking – otherwise it cannot be 'measured' (Ellis et al., 2005: 242; Kozma and Anderson, 2002) and (2) must demonstrate that instruments used to 'measure' it, such as COGITASK, are in fact measuring that construct. Both of these points are dealt with immediately below.

As regards (1) above, the critical thinking framework, developed in the previous chapter, provides a description of the construct, which has emerged from a broad, if not universal, consensus of opinion and, thus, is strongly supported in the literature of higher order thinking. This implies that the suggested theoretical framework is, at the least, a reasonably valid way of describing the construct.

As regards measurement of the construct, we have already touched on the respective merits of the COGITASK and the psychometric test as data collection methods. The shortcomings of psychometric tests are repeated here to highlight their implications for validity: psychometric critical thinking tests (1) are not authentic tasks and are, therefore, vulnerable to the charge that what they are measuring is not in fact critical thinking, (2) do not allow for the use of authentic tools, (3) do not measure domain-specific critical thinking (Kilpatrick, 1978), and (4) are often administered in artificial settings. The COGITASK, on the other hand, was shown to be a (1) *authentic* (2) *critical thinking* (3) *tool-based task* (4) situated in the *IPA context*.

Similar arguments, given here in a highly summarised format, can be made about the construct validity of OLD. OLD, as noted earlier, is an open-ended, unstructured, subject-centred data collection instrument which invites student-subjects to contribute what they deem to be important *to them*. The questionnaire, on the other hand, risks reflecting rather what the researcher deems to be important. If the research claims that it is reporting what is important to participants, then, one might argue, the OLD method has a stronger claim than the questionnaire to asserting that it is, in fact, measuring what it is purporting to measure.

Furthermore, online discussion (the use of professional fora, blogs, wikis, etc.), unlike the questionnaire, is itself an authentic task and has become an increasingly common method of working for IT professionals.

Finally, the completion of authentic critical thinking tasks and online discussions such as COGITASK and OLD are an integral part of MIS instruction (cp. Greenlaw and DeLoach, 2003), psychometric tests and questionnaires are not. The danger is that the latter, if used, are added on at the end of a module simply for the purposes of research. Students may respond to this in unanticipated ways that might affect the interpretation of the results.

Internal Validity

A study can be thought of has having internal validity if it plausibly demonstrates the causal relationship between 'treatment' and outcome (Robson, 2002: 103; Yin, 1994: 36).

Internal validity is an important requirement of fixed design explanatory studies. Although this is not a fixed design explanatory study, nonetheless, the principal methods in it can be shown to be quite robust (Appendix 3.3) in relation to any standard list of threats to internal validity, such as those of Campbell and Stanley (1963).

External Validity

A study can be said to have external validity when the extent to which its findings apply (or can be generalised) to 'populations, settings, treatment variables and measurement variables' (Campbell and Stanley, 1963: 175) other than those that were the subject of study (Robson, 2002; Gomm et al., 2000).

Randomisation and replicability, the cornerstones of the above conceptions of external validity (Krathwohl, 1985: 123), are not practical for the kind of authentic study envisaged here. The primary purpose of this research is not to make inferences about a known *population*. Thus, the students in this study are not a random sample of all IPA students, nor are the four cases/COGITASKS presented here a random sample of all possible cases/COGITASKS that could be presented. Such random sampling is not required since the purpose is not to make generalisations about a population but about a *theoretical domain*, in this case, the domain of (tool-enabled) critical thinking. That is the nature of the external validity claimed for this study (Yin, 1994: 37).

The discussion above implies that external validity, in the way that it has been characterised in fixed designs, is a virtually unattainable goal in flexible research designs, such as this one. Consequently, various re-conceptualisations of external validity have appeared[4]. Virtually all such re-conceptualisations question the assumptions and suitability of earlier conceptions of external validity, distance themselves from its stringent requirements and espouse the notion that

> 'The goal is not to produce results that can be replicated but a coherent description of a situation consistent with detailed study of it' (Ward-Schofield 1993:202).

This study's research design supports generalisation in the following ways:

Typicality: The MIS students are, designedly, not a random sample from the IPA student population. They are, however, as noted in Chapter 1, typical of IPA accredited

[4] In such re-conceptualisations the term 'external validity' is being gradually replaced by a new range of terms. These include the following: 'generalisability' [Schofield]; 'fittingness' [Lincoln and Guba]; 'comparability and transferability' [Goetz and LeCompte]; 'naturalistic generalisation' [Stake] (Ward-Schofield, 1993).

programme students in that they are paid public servants, mature, part-time students, pursuing a course which emphasises higher order thinking skills.

Generality: While the COGITASKS are centred on one specific subject-domain, information systems, they can be generalised to different domains. For instance, the customer-centered website task (hypermedia) for IS students can be converted into an advertising site for marketing students.

The tools used in the study to support these tasks are neither specialist nor bespoke. They are typical *general* purpose tools: spreadsheets, databases, PowerPoint that can be used for an almost infinite number of applications.

Thick descriptions: For example, in Chapter 1, thick descriptions of the MIS course and the MIS students have been provided. It is hoped these will facilitate 'repeatability' as well as allowing others to gauge the degree to which findings in this study's context are transferable to contexts in which they are interested.

3.5.3 Methodological Triangulation

This study uses triangulation at both data collection and analysis stages to corroborate its validity. For example, the methods COGITASK and OLD are triangulated to collect artefactual and perceptual data. The data are analysed using quantitative and qualitative approaches (Qualitative methods complement the quantitative descriptions of critical thinking performance and provide insights into the mechanisms by which, and the conditions under which, that performance is activated (Erickson and Nosanchuk, 1988; Ellis et al., 2005)).

Reliability

The multiple case study has been designed so that tasks (cases) are classified by the tool categories, Hypermedia and Modelling. Thus within each category there are two cases. These *within category* replications give the researcher some idea of the degree to which critical thinking performance fluctuates between similar cases.

The COGITASK method generates 'scorable' artefacts. The reliability of the scoring procedure is discussed in Chapter 4. The OLD method generates text-based narrative. Content analysis is used to analyse this data. The reliability of this procedure is discussed in Chapter 5.

In general the research design emphasises procedures to ensure that all relevant data is collected, secured and made appropriately accessible.

In addition, data collection and analysis procedures are reasonably transparent. For example, the codebook, used to analyse the OLD transcripts, is appended (Appendix 5.1). This provides detailed guidance on definitions, categories and rules to guide the coding process. Thus, the reader, by applying the standard procedures to the above data, will be able to reconstruct or 'replicate' the research and assess the reasonableness of the research findings (Kozma and Anderson, 2002).

The design envisages the provisional results of the research will be presented to and discussed with the directors of the accredited programmes in the IPA. The purpose of this will be to avoid any unilateral, idiosyncratic interpretation and thereby strengthen the reliability of the findings of the research.

The trustworthiness of the study's design and methods is summarised in the table below.

Table 3.2: Summary description of the trustworthiness of the study's design and methods

	Construct	Internal	External	Reliability
Design	Non-idiosyncratic 'definition' of critical thinking Cogent theoretical framework Use of authentic tasks vs. artificial tests	Not a requirement but is robust in relation to most of Campbell and Stanley threats to internal validity	Generalisation to a theoretical domain not to a population Typicality of MIS student-subjects Located within a particular context	Use of literal and theoretical replication Proofing Chain of evidence Transparency of procedures
Methods	Use of authentic tasks vs. artificial tests	Not a requirement but Is robust in relation to most of Campbell and Stanley threats to internal validity	Tasks representative of other critical thinking tasks in other domains Tools are *general* purpose Typicality of MIS student-subjects	Reliable scoring procedure Reliability of content analysis-codebook Transparency Triangulation of COGITASK and OLD methods Triangulation of manifest and latent content analysis

3.5.4 Ethical Considerations

As regards ethical considerations, it is worth noting at the outset that the data being collected is not of a sensitive nature, such that would cause, in the unlikely event of disclosure, detrimental effects to the individuals involved. Nonetheless, considerable care, in accordance with the university's ethical guidelines, has been taken to prevent such disclosure (Given the nature of the research, disclosures *by the participants* of illegal or harmful behaviour were deemed highly unlikely. None in fact occurred).

The data collection methods, COGITASK and OLD, were carried out in such a way as to bear no recognisable participant identifiers, such as a signature or a photo. Identities are known only to the researcher. Similarly, the data were analysed in such a way as to maintain the anonymity of individuals. Thus, data analysis is reported only in aggregate and summary form. Furthermore, in the presentation of the data, such as when an OLD transcript segment is quoted, participant identities are anonymised by means of pseudonyms. A passworded key to the pseudonyms is maintained separate from the main data storage location. In accordance with data protection guidelines for security and accessibility, data has been stored on one IPA network location, accessible only to the researcher, secured by passwords and permissions, and backed up on another.

The fact that the research is rooted in the real-life context of the IPA meant that the participants studied were students attending an authentic course of study and not assembled ('artificially') solely for the purposes of research. Consequently the role of researcher and teacher were interwoven in one and the same person, the author. Where there was ever a clash between teacher and researcher roles, the role of teacher always took precedence. Thus, if students needed help in an exercise they were always given it. Students were never denied help for ‘the sake of the validity of research’ (For instance, when designing exception reports for the EIS COGITASK I might give a student group, in need of more technical information, a short 5-10 minute tutorial in relation to a technical matter such as ‘conditional formatting’).

The combination of teacher and research roles also implies that the teacher is part of the research object. The reflections at the end of each chapter are designed to help the reader get a feel for the author’s perspectives and to determine the extent to which these might be influencing the interpretation of the data. It is appropriate that the voice of the author is heard but to avoid any undue weight that might be given to it, it is, of course, balanced by the voice of the student who is heard extensively, especially in Chapters 5 and 6.

The research participants were students on a real-life course in the IPA. Students were sent a letter of consent after they had finished their studies and been awarded their qualifications. This was to minimise any possible fear that a student might have about the negative consequences of not participating and also to minimise the possibility that students might embellish their OLD responses so as to put them in a favourable light with the tutor/ researcher. A copy of the letter is attached in Appendix 3.4.

This section has discussed the methodological issues, including the choice of a mixed methods approach, the measures taken to ensure validity and reliability, the importance of authenticity as a guiding principle, as well as a discussion of ethical issues.

3.5.5 Pilot Evaluation of Methods

A small pilot was designed to evaluate the COGITASK and OLD methods. In general the results of the pilot were encouraging. The students engaged in the pilot tasks enthusiastically. The methods were easy to use, non-disruptive and, largely, captured the rich objective and subjective data they were intended to capture.

The pilot raised some issues about the reliability of the marking scheme used to score performance on the COGITASK (Perkins and Murphy, 2006). As a result (1) the marking scheme was defined in greater detail (cp. Heron, 2006; McFarlane et al., 2000; Ferry et al., 1998) (2) more time was given to 'practicing' the marking scheme (Kozma and Anderson, 2002) (3) a system of blind scoring was adopted and (4) each COGITASK was marked twice.

A second reliability issue that emerged indirectly from the pilot relates to the consistency between the marking of one COGITASK and another. This was resolved by constructing one generic marking scheme for each of the different COGITASKs

The pilot showed the importance of ongoing guidance during the execution phase, especially at critical stages of the COGITASK. For the main study, a more structured system of intervention and guidance was implemented.

The pilot clearly showed that OLD is best conducted in the classroom when the experience is fresh in students' minds.

In the pilot, teams were pre-selected – not randomly assigned – in order to ensure that competence in technical tools was 'evenly' distributed across teams. (cp. Wiedenbeck et al., 2000; Ferry, 1998).

In the pilot OLD discussions, students occasionally seemed motivated by a desire to please the tutor rather than to express what they really felt. (e.g., exaggerated claims about their learning). This was not frequent but, nonetheless, sufficient to signal to the researcher to be on his guard for this in the main study.

The methods generate large amounts of data, which is rich, varied and messy. The pilot pointed to two implications for the main study (1) the need to set aside a considerable amount of time to coding (Perkins and Murphy, 2006: 302) and getting data into a format in which it can be satisfactorily analysed and (2) the need for a filing system to support the storage, retrieval and potential audit trails for COGITASK instructions, marking schemes, electronic artefacts, group composition records and spreadsheet result grids.

The relationship between the theoretical framework, research questions and the study's design and methods is summarised in the table below.

Table 3.3: Research Questions, Theoretical Framework, Research Design and Methods			
Theoretical Framework	A specific framework for critical thinking consisting of the following aspects: Constructive, Cognitive, Metacognitive, Knowledge and A Classification of Tools (esp. Hypermedia and Modelling)		
Design	Flexible, Multiple Case study, 4 Cases (tool-based authentic critical thinking task) classified by tool category *(Hypermedia and Modelling)* Mixed Methods Literal and theoretical replications		
Research Questions	**Data Collection Methods**	**Data Analysis Methods**	**Info expected from method**
1. Strengths and weaknesses What student strengths, weaknesses in the constructive, cognitive, metacognitive and knowledge aspects of critical thinking the use of such tools make visible?	COGITASK is an authentic tool-based critical thinking task which generates 'objective' numeric data, i.e., scores of critical thinking performance,	Quantitative techniques of exploratory data analysis: • Descriptive Stats • Frequencies • Graphical techniques • Stem and leaf plots	Will provide quantitative information on overall critical thinking performance and of differences in that performance between tool categories, COGITASKS and features within COGITASKS and more generally information on observed student strengths and weaknesses in tool-based critical thinking, made visible by the use of cognitive tools.
2. Perceptions of students of strengths and weaknesses What are the perceptions of students of their own strengths and weaknesses in relation to their	OLD, OnLine Discussion forum, a narrative account of which provides text-based data providing	Qualitative techniques of data analysis:	This method is designed to generate qualitative data on students' *perceptions* of their own strengths and weaknesses and thus provides insights into

critical thinking performance? What is the relationship between these perceptions and the findings at 2. above?	qualitative data in relation to student perceptions about critical thinking performance.	• Textual analysis • Content analysis	the metacognitive aspects of critical thinking especially in relation to task, strategy and people.
3. Mechanisms and conditions By what mechanisms, and under what conditions do certain hypermedia and modelling cognitive tools enable critical thinking? What are the critical thinking effects they enable? Are the enabling mechanisms, conditions and effects dependent on the tool category?	COGITASK & OLD (as above)	(as above)	(as above)
4. **Implications for teaching** What are the implications for teaching and learning in the IPA context? How might the findings be translated into a set of practical guidelines or 'rules of thumb' which IPA tutors can use?	COGITASK & OLD (as above)	(as above)	(as above)

3.6 Chapter Summary

This chapter has discussed the research design, methodology and methods to be adopted in order to answer the research questions. It justifies the choice of a multiple case study and of a mixed method approach and also evaluates the trustworthiness of the design. In relation to the methods, the chapter justifies the choice of the two principal methods, COGITASK and OLD, to be employed and provides a full discussion of their trustworthiness. It concludes by showing the relationship between the research design, methods and the research questions. The next chapter moves from research design to presenting an analysis of the empirical COGITASK data.

3.7 Reflection

Many years ago, I used to teach statistics. So, I might be described as a positivist by training. This has meant that I brought certain ideas with me about what constituted effective research designs. Even prior to the research I had an implicit idea about my research design: namely that there was (1) one right design (almost!) and (2) that it would be a fixed design of some kind producing data that would be amenable to statistical analysis.

My actual experience was to lead me away from such notions to a different way of designing the research and a different way of thinking about the world I was inhabiting and researching.

I had to re-learn that the world was uncertain, not easily captured by statistical models and that any attempt to do so was likely to be counterproductive. Even the terminology of research – such as strategy, methodology, methods – did not have universally accepted definitions. The object of my research – critical thinking (and cognitive tools) – was amenable to multiple definitions and, consequently, 'measurement' of such an object was also likely to be problematic. Indeed, I discovered how difficult it was even to formulate clear-cut research questions, never mind arrive at clear-cut answers to them.

Thus, much of my learning revolved around me coming to terms with the investigation of a world where the laws that governed it were different from those of the natural sciences and trying to strike a balance between my prior and my newfound knowledge. This is reflected in the chosen research design which contains both an objective and subjective element - in itself a reflection of my prior training and newfound understandings.

I believe the design is reasonably appropriate in that it provides, at least, provisional answers to the main research questions, and emphasises the importance of trustworthiness. I am not sure what I would change if I were doing it again, and with more resources available to me, but I think I would consider the use of psychometric tests to triangulate with the data from my research and also I would conduct in-depth interviews with the students.

Much of my life has been spent dealing with uncertainty. For instance, at work I have always tried, through careful attention to planning and scheduling, to implement information systems with a view to reducing uncertainty and error. Likewise, I devoted myself to statistics and the quantitative side of management science because I thought such approaches could produce the right answers to management problems. Much of this is laudable and such approaches can produce some answers that are reasonably right, but when taken to extremes they are the equivalent of trying to stop water gurgling out of the leaky bucket of life.

Now instead of trying to control the world, I have decided simply to accept its uncertainty and learn to make provisions for dealing with it. This applies to my work but also to the research design described here. The design makes no pretence to straightjacketing the world into treatment and control groups or to delivering a certain truth – the right answer. Instead, it attempts, within a well-planned framework, to deal with all the residual uncertainties of interpretation by means of the usual devices for supporting trustworthiness.

CHAPTER 4: STRENGTHS AND WEAKNESSES OF STUDENTS' CRITICAL THINKING (RESEARCH QUESTION 1)

4.1 Introduction and Purpose

The previous chapter presented a multiple case study research design encompassing two principal methods, COGITASK and OLD, generating quantitative and qualitative data respectively. Moving from design to analysis, the purpose of this chapter, based on a quantitative analysis of the COGITASK data only, is to address Research Question 1, which deals with observed student strengths and weaknesses in tool-based critical thinking, made visible by the use of cognitive tools.

The chapter first reviews the research question and framework, next analyses the data in terms of categories, features and items and finally presents findings. The chapter also shows how the student strengths and weaknesses are related to the theoretical framework.

4.2 Research Review: Research Questions, Theoretical Framework and Methodology

This chapter addresses Research Question 1.

Table 4.1: Research Question 1
1. Strengths and weaknesses in critical thinking What strengths or weaknesses in the constructive, cognitive, metacognitive and knowledge aspects of critical thinking does the use of cognitive tools make visible? Do any patterns emerge that are related to category of tool or type of task?

4.2.1 Theoretical Framework

The theoretical framework for critical thinking, developed in Chapter 2, characterises critical thinking as constructive, cognitive, metacognitive and knowledge-based. This framework is used to guide the analysis and interpretation of the data discussed in this chapter. This chapter focuses only on the constructive, cognitive and knowledge aspects of critical thinking. The metacognitive aspect is discussed in the next chapter.

4.2.2 Methodology

The research has been designed as a small scale multiple case study in which MIS students engage in four authentic critical thinking tasks – cases – using general purpose authentic Hypermedia and Modelling cognitive tools. Each case requires the production of electronic artefacts such as a website or a spreadsheet model (cp. McFarlane et al., 2000).

The overall design envisages two principal, complementary methods of data collection, COGITASK and OLD. This chapter discusses only the COGITASK data. The COGITASK method is designed to capture objective empirical data and is used to generate a quantitative analysis of strengths and weaknesses in students' *performance* on an authentic critical thinking task (Appendix 3.1). This is summarised in the table below.

Table 4.2: Research Question 1 with corresponding methods of data collection and analysis

Research Question (abbreviated)	Data Collection Methods	Data Analysis Methods
Observed Strengths and weaknesses in tool-based critical thinking	COGITASK= an authentic tool-based critical thinking task which generate numeric data	Quantitative techniques of exploratory data analysis: • Descriptive Stats • Frequencies • Stem and leaf plots • Graphical techniques

4.2.3 Methodological Issue: Trustworthiness of the Marking Scheme

Theoretical framework

Trustworthiness has been dealt with generally in the previous chapter. This section deals specifically with the trustworthiness of the marking scheme (MS), used to score the data collected from the COGITASK. It focuses on the construct validity of the MS, its reliability and some other trustworthiness issues relating to the MS.

As regards construct validity, the COGITASKS are authentic information systems (IS) tasks. The MS used to score them also arises out of the authentic world of IS. Therefore, the MS sections and items can be considered as practice-constituted criteria (Usher, 1996: 26-27). In other words, such are the criteria that experienced IS professionals are likely to use, in the world of work, to make judgements about IS artefacts such as web-sites and EIS models. The question – a construct validity question – now arises, however, as to what extent the practice-constituted criteria are indicators of the cognitive skills required for critical thinking, which the MS purports to measure.

Bloom's taxonomy is one description of the skills in the cognitive domain. The table below compares the MS against the categories[5] in Bloom's domain. The table shows a close correspondence between Bloom's categories (columns 1 and 2) and the corresponding MS section (column 3). For each section of the MS, column 4 gives an example from the EIS COGITASK to illustrate that correspondence.

[5] The MS for the COGITASK does not include Bloom's 'Evaluation' category. This is captured by the OLD method and discussed in the next chapter.

Table 4.3: Correspondence between MS and Bloom's cognitive domain categories

Bloom's categories	**Description of Bloom's category**	**Description of corresponding MS Section**	***One* Example (from the EIS COGITASK)**
Remember Understand	'Remember', 'Understand', include recognition, recall and comprehension of knowledge and the ability to order, compare and make sense of data.	**Content/Knowledge** scores ability to recall and understand conceptual knowledge (and relate it to a work-related context).	In an EIS Cogitask, a student demonstrates proficiency in this section of the MS when, for instance, s/he uses the tool to input the (recalled) key conceptual components of the EIS model and to assign data to each in a way that makes sense.
Apply	**Apply** includes the use of information, knowledge, methods, tools and skills to solve problems in different contexts.	**Functionality** scores ability to apply conceptual knowledge and understanding through skilled use of tool features/functions in order to create a functional artefact.	In an EIS Cogitask, a student demonstrates proficiency in this section of the MS when, for instance, s/he uses the tool to enforce relationships between raw and summary data, thus applying conceptual knowledge and understanding of the concept of EIS 'hierarchy'.
Analyse Create	**Analysis** includes the decomposition of the whole into its component parts, including ordering, classification and arrangement of these parts.	**Structure & Construction Construction 1** section scores ability to decompose the task into its component parts and to structure these into levels.	In an EIS Cogitask, A student demonstrates proficiency in this section of the MS when, for instance, s/he decomposes the EIS model into components (e.g., Key Result Area (KRA), Indicators, Targets) and s/he uses the tool to assign components at different levels to workbooks, worksheets, ranges, cells (in accordance with an overview of overall design).

	Create includes the assembly or synthesis of multiple parts into a coherent whole.	**Structure & Construction** **Construction 2** section scores ability to synthesise components and knowledge into a coherent whole	In an EIS Cogitask, a student demonstrates proficiency in this section of the MS when, for instance, s/he uses the tool to develop a menu system which synthesises separate works*heets* into a coherent model (work*book*) or s/he uses the tool to automate some function, e.g., data import.
Analyse Create	See above	**Layout** section scores ability to analyse the required page layout and assemble page level objects, relative to one another, in conformance with usability and aesthetic criteria.	In an EIS Cogitask, a student demonstrates proficiency in this section of the MS when, for instance, s/he analyses page layout requirements and s/he uses the tool to position, size, format and assemble objects – titles, menus, data, images – relative to another.

The table above shows a close correspondence between the practice constituted criteria of the MS and the cognitive skills required for critical thinking and thus strongly corroborates the construct validity of the MS.

The second trustworthiness issue deals with the reliability of the MS, which in this context refers to the stability and consistency of the MS scores. In general the scoring was quite stable. Each COGITASK was scored twice. The scores were correlated and the correlation coefficient of $r = 0.88$ ($p<.0.05$) was computed. The coefficient supports the intra-rater reliability of the scores.

Difficulties in Devising COGITASKs MS

There are also some other minor trustworthiness issues. The four COGITASKS are different. It was decided, however, to devise a *single* Marking scheme (MS) to cover all four. This was deemed necessary to facilitate comparisons but it causes a problem of 'translation' in form. Thus, the MS item 'Graphics' in an EIS COGITASK may take the form of a trend-line chart, whereas in the BPR COGITASK this may be translated to take the form of a Data Flow Diagram. (Most MS items, however, translate reasonably well from one COGITASK to another)

Within each COGITASK, the MS must also accommodate differences. Each task may be executed 'successfully' in different and unexpected ways. Therefore, it is not easy (or desirable) to specify the scheme in great detail, in advance. Consequently, the MS attempts to provide directive guidance but also to allow for flexibility.

Ideally, MS items should be completely independent of each other but some overlap is difficult to avoid. For instance, the execution of functional navigation links in the Structure & Construction section may be related to the navigation layout in the Layout section. Such overlaps may well reflect the fluidity of the underlying construct: boundaries between 'constructive' and 'cognitive' or between categories such as 'apply', 'analyse' and 'create' are not completely independent.

The distribution of the marks across the four sections - Content/knowledge (25), Structure & Construction (25), Functionality (30), Layout (20).- reflects the fact that Functionality was deemed to be cognitively more difficult and Layout less difficult, than the other sections. MS items are scored in 4 or 5 marks units. It might be argued that 1 mark units might support finer distinctions. It was felt better to retain 5 marks units in the interest of balance between directive guidance but also to allow for flexibility

Differences between each COGITASK and within each COGITASK in terms of execution, independence of the MS items and the weighting of the marks are all areas where the marker may have to make subjective judgments. Thus, it is a useful reminder that something such as a critical thinking performance (CTP) score may be underpinned by several small, but cumulative, subjective judgments.

4.3 Analysis: Introduction

The study now proceeds to the data analysis. The quantitative methods and techniques, known as exploratory data analysis, are used here to analyse the COGITASK data (Erickson and Nosanchuk, 1988; Ehrenberg, 1982; Tufte, 1986). These methods, ideal for the analysis of compact data sets, such as the one presented here, strongly support the generally idiographic approach taken to the research and analysis, where this approach is characterised by the thorough study of a small number of cases (Brown, 1992). The analysis of the data takes place at three progressively more detailed levels (1) a broad analysis of Tool Categories and COGITASK (2) a more detailed analysis of Tool Features within COGITASK and (3) an analysis of Tool Items within Features (The reader may find it useful, at this stage, to consult Appendix 3.1 for a detailed description of the COGITASK).

4.3.1 Analysis of Data: Level 1: Broad Analysis of Categories

This section addresses that part of Research Question 1 which deals with emergent 'patterns related to category of tool or type of task' and, therefore, examines the data for effects attributable to Tool Category and COGITASK. In each of the above, we discuss the average, the variation, the shape of the data (where relevant) and how we might interpret this data in relation to tool-based critical thinking. We begin by looking at the overall critical thinking performance scores (CTP), summarised in the figure below.

Fig. 4.1: Stem and Leaf plot of 18 CTP scores

Stem	**Leaves**
8	
8	23
7	557
7	02
6	5568
6	0
5	58
5	14
4	5
4	2
0	

The stem and leaf plot shows the distribution of CTP scores centred on an average in the mid-60s (median = 67, mean = 65). However Fig 4.1 clearly shows that, while there is some clustering of values around the average, the values are also spread out across all classes of the plot. For instance, the range, a measure of the variation in data, is 83 - 42= 41. This range value, 41, approximately 60% of the median, is indicative of considerable variation in the data.

Interpretation

This might be interpreted as saying that while CTP is on average reasonably high, it is also subject to large amounts of fluctuation.

Tool Category Effect on CTP

Turning now to the relationship between CTP and Tool Category, the tables below compare the CTP scores and summary statistics for the Hypermedia and Modelling tool categories.

Table 4.4: 18 CTP scores, classified by Tool Category					
Tool Category					
Hypermedia	58	42	75	65	
	51	66	83	55	
Modelling	45	77	72	82	65
	60	70	54	68	68

Table 4.5: CTP summary statistics, classified by Tool Category		
Statistics	**Modelling**	**Hypermedia**
Max	82	83
Q_U	72	75
Median (Md)	62.5	62
Mean	66	63
Q_L	58	53
Min	45	42
Range (R)	37	41
(R/Md)	59%	66%

From the table immediately above one can see the average (median) scores for both the Modelling (62.5) and the Hypermedia (62) categories are almost identical (The mean scores are also very similar, 66 and 63 respectively). In addition, variation in both tool categories is also comparable: the respective ranges are 37 and 41. Finally, the actual maximum and minimum values are very similar, 82 and 83, 45 and 42, respectively, as indeed are the upper (QU) and lower quartile (QL) values.

In general, the variation is large but consistent from category to category. The most striking feature of the data presented above is that the two categories are almost identical in terms of their averages, variation and shape.

Interpretation

There is insufficient evidence to claim that CTP is affected by Tool Category.

The data strongly indicates that tool CATEGORY is not a critical factor determining CTP. For example, the average scores indicate that students do not find it either easier or more difficult to work with Hypermedia tools or Modelling Tools.

The striking similarities between the categories in terms of averages, variation and shape, perhaps indicate that Hypermedia and Modelling categories may be, in fact, sub-categories of a homogenous 'population' of tools and, consequently, have inherited the characteristics of their parent category. If that is the case, there is no reason to suppose that the mechanisms by which one tool category achieves its effects are different from the other.

CTP, overall, is subject to large amounts of fluctuation. This cannot be accounted for by differences between the tool categories, since variation is similar for each category. It may, however, be related to the nature of the tasks themselves, which as we noted above, can be executed 'successfully' in different and unexpected ways.

COGITASK Effect on CTP

We now turn to the relationship between CTP and COGITASK. The tables below compare the CTP scores and summary statistics across the four COGITASKs.

Table 4.6: CTP scores classified by COGITASK
(H-=Hypermedia, M-= Modelling)

Task					
H-Customer Web	58	42	75	65	
H-Online Tutorial	51	66	83	55	
M-EIS	45	77	72	82	65
M-BPR	60	70	54	68	68

Table 4.7: CTP summary statistics classified by COGITASK
(H-=Hypermedia, M-= Modelling)

Task	Ave	Max	Min	Range	Range/Ave
H-Customer Web	63	75	42	33	53%
H-Online Tutorial	64	83	51	32	50%
M-EIS	68	82	45	37	54%
M-BPR	64	70	54	16	25%
Overall average	65				

The salient feature of the data presented in the table immediately above is, once again, the consistency of the average scores for each COGITASK. The averages are all clustered in a narrow band in the 60s, between 63 and 68.

The variation in CTP on each COGITASK is also similar. The ranges are, mostly, in the mid-30s. The range values for each task are also very large. In three cases variation, as measured by range as a % of average, is 50% or more of the average value.

Interpretation

There is insufficient evidence to claim that CTP is affected by COGITASK. The data strongly suggests that the COGITASK is not a critical factor determining CTP. Each of the average scores is consistent with each other and with the overall average (this implies, for example, that students did not find one specific critical thinking task either easier or more difficult than others).

The overall mean CTP score is 65. Furthermore, the mean CTP scores for Tool Category (66 and 63) and COGITASK (63, 64, 64, 68) are very consistent with both each other and the overall average. Both of the above results probably reflect that there are a large number of variables which affect CTP and produce an averaging effect.

The variation in CTP, as measured by range, on each COGITASK is similar and large – up to 60% of the overall average score. The large variation in CTP also remains roughly constant across Tool Category and COGITASK. This indicates that CTP scores fluctuate a lot both within the same tool category and within the same task. This might mean that while performance on each task is, on average, reasonably high, it is also rather 'hit and miss'.

Overall, there is insufficient evidence to claim that CTP is affected by either (1) Tool Category or (2) COGITASK. Indeed it is the similarities between CTP in different Tool Categories and COGITASKs that is striking.

4.3.2 Analysis of Data: Level 2: Features within COGITASK

We now turn to a more detailed analysis of Features within COGITASK. Each COGITASK consists of four features: Content/Knowledge, Functionality, Structure & Construction and Layout.

We begin with the table below which presents a comparison of CTP scores across the four features.

Table 4.8: The average rounded standardised scores for the four COGITASK features

Feature	**Ave**
Content/Knowledge	78
Functionality	51
Structure & Construction	65
Layout	65
Totals	

From the table above it is clear that CTP is affected by performance on features within the COGITASK. For instance, the average score for the Content/Knowledge feature is 78 but only 51 for the Functionality feature. Thus performance is not uniform across features: scores for Content/Knowledge are, relatively, high; scores for Functionality are, relatively, low and the scores for the other two features are somewhere in between.

Interpretation

The high scores for Content/Knowledge might be accounted for by the fact that the Content/Knowledge feature of the COGITASK consists mostly of written text. It is the feature which most resembles the traditional form of assessment and the one most familiar to students. Therefore one might expect students to perform better on this aspect of the task.

The low scores for Functionality may reflect, on the students' part, a lack of technical skill or an underdeveloped ability to translate their understanding into a working artefact. This is explored further below.

Fig. 4.2: Back to Back Stem and Leaf Plot of scores on the Content/Knowledge and Functionality features (Score range 0-25)		
Leaves	**Stem**	**Leaves**
25, 25, 25, 25	**22.5**	
20, 20, 20, 20, 20, 20, 21	**20.0**	21
18	**17.5**	19,18
15,15, 17	**15.0**	17,17
	12.5	15,13,13,13,13
11	**10.0**	12,12,11,11
	07.5	9,8,8
	05.0	
	02.5	4
	0.0	
Content/knowledge		**Functionality**

As regards variation in performance, from even a brief look at the figure above it is fairly obvious that there are differences in variation between the Content/Knowledge and Functionality features. For example, the values for Functionality are spread up and down the graphic. The Content/Knowledge scores, however, are clustered in the left, upper third of the graphic – in fact 11 of the 18 scores are to be found there. Thus, the Content/Knowledge average is high but its variation is small. The opposite is the case for the Functionality features – its average is low but its variation is large.

The average scores indicate that students perform better on the Content/Knowledge aspects of critical thinking, while the variation patterns indicate that they can also repeat that performance much more consistently. In other words, students' performance on Functionality is not only lower than on Content/Knowledge, it is also subject to more fluctuation.

This suggests that although in general students (1) may perform better on one feature than on another, such as on Content/Knowledge and Functionality, nevertheless, (2) even *within* each feature there can be a wide variation in performance.

Relationships between features

We have looked at some differences between the features. We now look at possible relationships or associations between features.

Table 4.9: Correlation coefficients, with P values (in bold) underneath, for four features

Feature	Content	Structure	Functionality
Structure	0.30		
	0.23		
Functionality	0.06	0.25	
	0.82	**0.31**	
Layout	0.42	0.26	-0.09
	0.08	**0.30**	**0.73**
Totals			

From the table above, it can be seen that, in general, the relationships between features are very weak. For instance, none of the correlation coefficients are greater than 0.5 and none of the P-values are statistically significant. For instance, the correlation of 0.05 between content/knowledge and functionality suggests that there is little or no association between these two features. The same applies to the associations between the other features.

Interpretation

The finding that there is little or no association between features, such as between Content/Knowledge and Functionality, appears initially to be counterintuitive. For instance, in the case of the EIS COGITASK one might expect students who excel in their knowledge of what an EIS model is, to also excel in their functional capacity to apply their conceptual understanding to the building of an EIS model. This, however, does not appear to be the case. As already noted, this points not to a lack of knowledge on the students' part but to an underdeveloped ability to apply what they know – a recurrent theme in this study.

4.3.3 Analysis of Data: Level 3: Items within Features

Having looked at features, we now proceed to a more detailed analysis of items within the four features (1) Content/Knowledge (2) Functionality (3) Structure & Construction and (4) Layout. There are in total 26 items across the four features (Appendix 4.1).

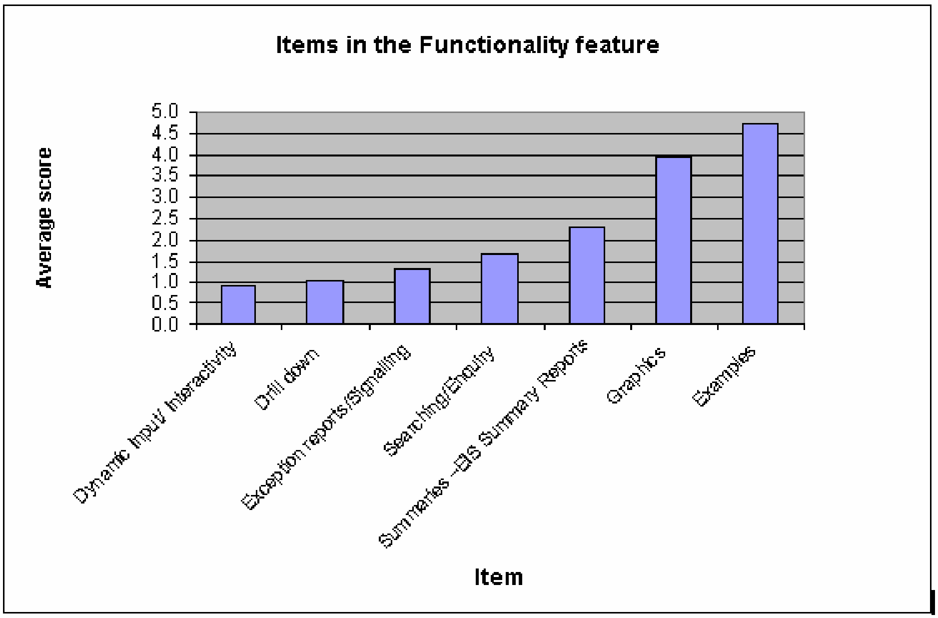
The figure below shows the distribution of all items across all four features.

Fig. 4.3: Stem and leaf plot of average scores for 26 items across all features (Score range 0-5)

Stem	**Leaves**
4	7577
4	32
3	988877
3	44
2	987
2	43
1	77
1	314
0	9
0	

The shape of the plot shown is a little unusual. It is bimodal. The data seem to cluster around two areas rather than just one. For instance, the data clusters around the high 4s and the high 3s. Examining the high 4 data we find that it consists, mostly, of the scores for items in the Content/Knowledge feature and the Layout feature. However, the four lowest scoring items, 'Drill Down', 'Interactivity', 'Exception Reports' and 'Searching', are all items in the Functionality feature.

Fig. 4.4: Column chart of average item scores for the functionality feature



The Functionality feature is indicative of the skill with which students use tool functions to apply conceptual knowledge in order to make an artefact. These data suggest that students have difficulties in this regard.

Turning to the figure above, two groups of items stand out fairly clearly: the high score items in one group – 'Examples', 'Summaries' and 'Graphics' items – on the far right, and the remaining (relatively) low score items – 'Drill down', 'Dynamic Input/Interactivity' and 'Exception Reports' items on the left.

Perhaps one reason why 'Examples' and 'Summaries' items attract high scores is that they have a strong descriptive element. Secondly, traditional written assessment assignments, to which students are accustomed, often require students to summarise or 'illustrate with examples'. Since students are familiar with such items, the requirement to provide summaries or examples is understood more readily.

The high score for the 'Graphics' item is partly attributable to the fact that students readily understand the requirement and partly, perhaps, to the fact that MIS technical students enjoy 'playing' with software features, like graphics. It is fun. In addition, this score perhaps reflects a misconception, common among MIS technical students, which results in a tendency to judge software on the basis of features (not benefits!). Graphics are the most striking feature of a piece of software, so its not surprising that MIS students might devote more time to this feature than to others.

The three lowest score items are 'Drill Down', 'Dynamic Input/Interactivity' and 'Exception Reports'.

Since the 'Drill Down' item requires students to build technical links between data at a number of different logical levels, the low score for the Drill Down item is suggestive of (1) a lack of depth of understanding, and (2) an underdeveloped ability to transform their understanding into an artefactual feature or to make the connection between the conceptual 'knowing what' and the technical 'know how'.

The low score for the 'Dynamic Input/Interactivity' item may reflect the technical difficulty of this item. For instance, the EIS modelling task may require the use of advanced features, such as macros. Secondly, the task requirement is not immediately obvious: For instance, when creating a Hypermedia tutorial, the composition of the electronic narrative appears, at first glance, to simply replicate manual composition. In fact, the exploitation of interactive items, such as a quiz, requires the student to think differently – in a non-linear way – about the content and sequence of the tutorial composition and narrative.

As regards the third low score item, although students have no difficulty in understanding a paper-based exception report, the low score for the 'Exception Reports' item may reflect the difficulty students have in *visualising* how they might accomplish such exception reporting, electronically, in a modelling package. Like the 'Interactivity' item above, electronic 'Exception Reports' requires the student to think differently about the nature and structure of such reports.

Thus while students can avail of the functions within the tool in order to make an artefact, they often show, perhaps understandably, a lack of skill in the finer points of their use. The net effect of all this is that their artefacts tend to lack a 'professional' finish.

Structure and Construction Items

The Structure and Construction feature is indicative of the way students approach the design and making of the artefact. In particular it highlights (1) broad design issues, (e.g., design levels) and (2) component assembly issues such as the use of menus to integrate components.

In the table below, most of the average item scores are quite high, ranging from. 3.8 to 3.4, which suggest that students are reasonably good at constructing and assembling artefact components.

Table 4.10: Average item scores (Score range 0-5), for 6 items of the Structure & Construction feature

Items	**Ave**
Navigation: Menus Hyperlinked	3.8
Overview: Beginning-End	3.8
Navigation Ease of use	3.7
Overall design	3.4
Navigation links: Back/Home/Next	2.8
Overview: Design levels	2.7

More noteworthy, however, is the lowest score, 2.7, for the 'Overview: Design levels' item. Since the number of design levels is an indicator of the number of conceptual levels which students have taken into account in their conceptualisation of the artefact and in the formulation of their design, it is, like the 'Drill Down' item, an indication of depth of understanding. The low score for this item once again points to weakness in this area.

Layout Items

We turn now, very briefly, to an analysis of the Layout feature.

Table 4.11: Average item scores (Score range 0-5) for 5 items of the Layout feature.

Items	**Ave**
Sheet Title and Headings	4.3
Data	3.8
Menus	3.7
Navigation Placement & Layout	3.4
Other Items	2.3

The Layout items with the highest scores are 'Sheet Title and Headings', 'Menus' and 'Data'. This is hardly surprising since most people expect Sheet Titles to appear in a particular place, that is, the top of the page (this is not always adhered to; for instance worksheet titles in Excel appear at the bottom of the page). Similarly, there is a strong tradition – within and beyond the IT community – about the organisation, layout and placement of menus – on a top or left-aligned panel. It is not unreasonable, therefore, to suggest that students attain high scores on these items because, prior to engaging in these tasks, they have a clear idea 'in their heads' about how such items might be organised on the page; that is, the requirements of the task are in some sense familiar to them (cp. Bransford et al., 2002).

4.4 Chapter Findings, Research Question and the Critical Thinking Framework

This chapter addressed Research Question 1. The findings in relation to it are summarised below with reference to the critical thinking framework.

4.4.1 General

There is insufficient evidence to claim that CTP or student strengths and weaknesses are affected by category of tool or type of task (in fact, the similarities between them are striking). If that is the case, there is no reason to suppose that the mechanisms by which one tool category achieves its effects are different from the other.

4.4.2 Constructive Findings: Strengths and Weaknesses

Students are reasonably good at assembling components and subcomponents into the final constructed artefact. In general the artefacts they created worked but they lacked a professional finish.

Possible Explanations

Much of the working lives of these IT students is spent troubleshooting user problems and 'fixing things'. The finding above perhaps reflects the positive orientation of these technical students towards doing and construction rather than towards analysing and planning,

Component Assembly is a concrete activity. Being concrete it provides cues as to progress. Students receive tangible evidence of success. This can be motivating.

Prior to engaging in these constructive tasks, students have a clear idea in their heads about what the end result should look like. For instance, before embarking on the website COGITASK they will have seen lots of examples of websites.

Possible examples of tool-based mechanisms likely to enable effects related to Constructive aspects of critical thinking are Menus, Navigation features, Templates and the tool structure.

4.4.3 Cognitive Findings: Strengths and Weaknesses

Students perform worst on the Functionality feature, which suggests an underdeveloped ability to apply what they know. Indeed, it is noteworthy that of the 26 items that comprise all features, the four lowest scoring items – Drill Down and Interactivity, Exception Reports and Searching – are all items in the Functionality feature.

Nonetheless, students do a reasonable job of applying their understanding. This is especially the case where the application involves descriptive elements, or is familiar in some way, or where the requirement is well understood (e.g., use of graphics, summaries and examples).

There is evidence to suggest that students' understanding can be shallow. For example, the 'Drill Down' item and 'Overview: Design levels' item are both indicative of depth of understanding. Both receive low scores. This suggests that students do not spend enough time analysing the vertical (and lateral) relationships between concepts.

Possible Explanations

A possible reason why students do not invest enough cognitive effort in the planning and design phases of the task is that often the analytical work involved in them does not provide the concrete cues to progress available in the construction phases of the task.

Therefore, it is easy to get lost and difficult to know if one has achieved anything. This, in turn, can be de-motivating.

Depth of understanding – one of the hallmarks of the critical thinking expert – takes a long time to acquire (Lajoie, 2003). Thus a certain shallowness of understanding typifies naïve approaches to critical thinking.

Some aspects of the tasks are conceptually difficult, requiring high levels of abstraction. For instance, it can be difficult (1) to discover lateral relationships between components/entities and (2) to model them accurately.

Possible examples of tool-based mechanisms likely to enable effects related to Cognitive aspects of critical thinking are hyperlink, linked formulae, multi-level sorting and the tool structure.

4.4.4 Metacognitive

Findings related to the metacognitive aspect of critical thinking are discussed fully in the next chapter.

4.4.5 Knowledge

Findings: Strengths and Weaknesses

Students perform best on the Content/Knowledge feature.

Possible Explanations

Perhaps one reason why Content/Knowledge items attract high scores is that they have a strong descriptive element. The Content/Knowledge feature draws mostly on Bloom's 'remember' and 'understand' categories. Since these are the easiest cognitive skills to master, one would expect students to score high on this feature.

Content/Knowledge tasks are familiar tasks. Students are exposed to such tasks throughout their educational lives. Since they are familiar tasks one would expect students to perform well on them.

It is easy to visualise the electronic version of a content task. A hand written report does not look much different to one on a computer. Thus, the amount of transformation required to convert hand written content into their electronic counterpart is small.

Possible examples of tool-based mechanisms likely to enable effects related to Content/Knowledge aspects of critical thinking are templates, wizards and the tool structure.

The findings are set out in tabular form immediately below.

Table 4.12: Students' strengths and weakness, based on the COGITASK data, related to the theoretical framework	
Theoretical Framework Related Aspect	**Findings: Strengths and weaknesses, based on COGITASK data**
	Strengths
Constructive	Students are reasonably good at the **synthesising** aspects of the task – assembling components/ideas into artefact. The constructed artefacts *worked.* A strong orientation towards the importance of construction (rather than towards analysing and planning)
Cognitive	Students do a reasonable job at applying their understanding. This is especially the case where the application involves descriptive elements, or is familiar in some way or the requirement is well understood (use of graphics, summaries and examples).
Metacognitive	
Knowledge	Students perform best on the Content/Knowledge feature, esp. factual knowledge.
	Weaknesses
Constructive	The artefacts constructed lacked professional finish. Underdeveloped orientation towards analysing and planning
Cognitive	Students perform worst on the Functionality feature, which suggests an underdeveloped ability to apply what they know to authentic tasks and contexts. Understanding can be shallow and application of knowledge often lacking in depth. Students perform very badly on indicators of depth such as the Drill Down item and No. of Design Levels item. The analysis of the overall design is frequently inadequate.
Metacognitive	
Knowledge	Students perform less well on conceptual knowledge

4.5 Chapter Summary

This chapter addressed Research Question 1. It presented, at a broad and detailed level, a quantitative analysis of the COGITASK data. At a broad level it has concluded that there is insufficient evidence to claim that observed student strengths and weaknesses in tool-based critical thinking are affected by Tool category or by the nature of the COGITASK. At a more detailed level, it suggests that students are strong on Content/Knowledge and constructive aspects of the task. Student weaknesses include analysing and planning, applying what they know to authentic tasks, and shallowness of understanding. The chapter concludes by showing how observed student strengths and weaknesses in tool-based critical thinking made visible by the use of cognitive tools can be interpreted in the context of the theoretical framework.

4.6 Reflection

This chapter presents a quantitative analysis of critical thinking performance that emerged from a study of the COGITASK data.

The quantitative analysis, despite overt reservations about positivism in an earlier reflection, is a hint that such objectivist approaches are deeply rooted in me, partly, no doubt, as a result of my earlier statistical training. From the outset of the research, there lurked somewhere beneath the surface the secret belief that it was in fact possible to quantify and measure and arrive at definite conclusions about critical thinking, which could be corroborated by objective quantitative data. The history of working with this data was to lead me to a different place.

I can see now that I set out to find an objective measure of critical thinking by devising measurable task(s), by devising a quantitative marking scheme and by conducting a quantitative analysis in the hope, I think, that this would lead me to some objective truth.

In the course of my work, however, it gradually dawned on me that such claims to objectivity could not be sustained. For instance, it might be argued that the selection of tasks was subjective, the selection of items in the marking scheme (MS) was subjective or the weights attached to them were subjective, or the marking itself by the marker was subjective. All of these are valid caveats about the objectivity of the account produced here.

Accordingly, in the course of the research, I attempted to deal with these difficulties by selecting tasks that were at least *representative*, by employing a subset of statistical methods – exploratory data analysis – which emphasises exploration rather than statistical inference, and by focusing a lot of attention on accounts of interpretation. These were all reasonably effective actions but it is important to remember that we are still dealing with material that is inherently subjective.

As regards interpretation, I think it is obvious that I make a strong effort to make sense of the data and construct meaning from it. Thus, there are lots of sections devoted to interpretation of the data. I expend a great deal of effort working with the data at a very detailed level, citing evidence to corroborate interpretations yet also recognising the subjectivity of such claims (I think much of this approach is a general reaction on my part to journal articles where interpretations are offered on the basis of summary statistics without much evidence that the data has been explored).

I am continuing to learn the importance of safeguarding oneself against unwarranted interpretations as well as the importance of acknowledging at all times that in such matters these interpretations are subjective and subject to change – that is, being prepared to acknowledge the possibility of being 'wrong'.

CHAPTER 5: STUDENT PERCEPTIONS OF THEIR STRENGTHS AND WEAKNESSES IN CRITICAL THINKING (RESEARCH QUESTION 2)

5.1 Introduction and Purpose

The previous chapter, focusing on the COGITASK data, presented a quantitative analysis addressing Research Question 1. This chapter, based on both a quantitative and a qualitative analysis of the OLD data, addresses Research Question 2, which deals with students' *perceptions* of their own strengths and weaknesses and thus provides insights into the metacognitive aspects of critical thinking. The chapter first discusses the content analysis technique used to analyse the data, then interprets the students' perceptions of their performance, using the technique. It broadly concludes that students consider achieving the end result and teamwork to be their main strengths and a lack of technical capacity to be their principal weakness. In addition, the chapter points to another weakness – an underdeveloped metacognitive awareness. The parallels between findings in this and the previous chapter are brought out in the light of the theoretical framework for critical thinking.

5.2 Research Review: Research Questions, Theoretical Framework and Methodology

This chapter addresses Research Question 2.

Table 5.1: Research Question 2
Perceptions of students of strengths and weaknesses What are the perceptions of students of their own strengths and weaknesses in relation to their critical thinking performance? What is the relationship between these perceptions and the findings for Research Question 1?

5.2.1 Theoretical Framework

The theoretical framework for critical thinking, developed in Chapter 2, characterises critical thinking as constructive, cognitive, metacognitive and knowledge-based. The previous chapter examined the cognitive, constructive and knowledge aspects of critical thinking. In this chapter we focus on the metacognitive aspects of critical thinking.

This framework is used to guide the overall analysis and interpretation of the data.

5.2.2 Methodology

The overall design envisages two principal, complementary methods of data collection, COGITASK and OLD. This chapter uses only OLD data – an OnLine Discussion forum that contains narrative accounts of MIS students' reflections on their performance. The OLD method is designed to capture subjective empirical data about *perceptions* of performance on a critical thinking task. Content Analysis and Exploratory Data Analysis methods are used to analyse the OLD data.

Table 5.2: Research Question 2 and the corresponding methods of data collection and analysis

Research Question 2 (abbreviated)	**Data Collection Methods**	**Data Analysis Methods**
Perceptions of students of strengths and weaknesses	OLD (OnLine Discussion forum) narratives of student reflections which provides text-based data	Qualitative techniques of data analysis: • Content analysis • Exploratory data analysis

Metacognition, an important focus of this chapter, has been discussed in Chapter 2. Metacognition can be thought of as a sub-framework within the overall critical thinking framework. The metacognitive framework used here follows that of Flavell and others (Flavell, 1979; Pintrich, 2002). The framework consists of metacognitive knowledge and regulatory processes in relation to three key factors: Task, Strategy and People. This metacognitive framework is used to guide the specific approach to content analysis as well as to coding. For instance, the main coding categories – Task, People and Strategy – are derived directly from Flavell's work. This is important, since the absence of any clear guiding framework is one criticism commonly levelled at content analysis studies in recent reviews of its use (Rourke et al., 2001; De Wever et al., 2006; Kay, 2006). A second criticism is that frameworks, when present, can suffer from being overly complicated, such as that of Bullen (Bullen, 1998). This study attempts to provide, in the first instance, a guiding metacognitive framework and one which is, in the second instance, both simple and clear.

5.3 Content Analysis

This section presents a description of Content Analysis, indicates its benefits to this study and outlines the steps that will be followed in its adoption for this research.

Content Analysis is a set of research techniques and procedures designed to objectively and systematically analyse written or oral text-based communication. The Content Analysis procedure normally involves deciding on a coding unit (known as the recording unit or unit of analysis), coding the text at that unit level and then analysing the coded text, employing quantitative or qualitative methods or both (Bryman, 2001). The ultimate purpose of Content Analysis is to make inferences, based on the occurrence of certain words or phrases, about the meanings underlying the text (De Wever et al., 2006; Krippendorf, 1980). Rourke et al. (2001) discuss 19 applications of Content Analysis to online discussions, such as OLD data in this study, and De Wever discusses some 15 applications (De Wever et al., 2006; Guiller et al., 2008).

The principal advantages of Content Analysis for this study are:

- It is most suitable for analysing written text-based data such as the OLD data. Henri described content analyses of such data as 'a gold mine of information concerning ….the learning strategies adopted, and the acquisition of knowledge and skills' (1992).
- Content Analysis has been widely used in the study of critical thinking, higher order learning, cognitive and metacognitive skills (Henri, 1992; Fahy et al., 2000; Garrison et al., 2000, 2001; Rourke et al., 2001: 7-8/15).

- The same quantitative techniques which were applied to the analysis of the COGITASK can be applied to the OLD data.
- When the data is in electronic format, as is the case with the OLD data, it can avail of a wide range of software for analysis.

The principal disadvantage of Content Analysis revolves around the reliability of the technique. This is dealt with below.

5.3.1 Two Approaches to Content Analysis

There are two broad approaches to Content Analysis. The first, syntactic approach, referred to as Manifest Content Analysis, typically employs the single word as its recording unit, records the occurrence of each word, and based on the frequency of each word, makes judgements about the meaning of a text.

This approach has the operational advantage that once the coding rules have been established, the assignment of words to categories can be automated and analysed quantitatively. This in turn increases the reliability of the coding scheme – an important feature since reliability is probably the central methodological problem with content analysis.

The second approach, Latent Content Analysis, takes contextualised semantic 'units of meaning' – phrases, sentences, paragraphs, messages – as the recording unit and assigns these units to meaningful categories. The main drawback with the approach is that a high degree of inference may be required on the part of the researcher to assign the text to a category. This, in turn, raises reliability issues (Henri, 1991; Rourke et al., 2001).

This study uses, primarily, a fairly low inference latent approach but also avails of some of the procedures of manifest content analysis to cross check codes and results.

Within latent and manifest Content Analysis one can also distinguish between emergent and prescriptive generation of coding categories. In emergent coding, the researcher develops categories on the basis of the patterns that emerge in the course of the data analysis. In prescriptive or *a priori* coding, the researcher develops a set of categories prior to coding the data. This study uses both prescriptive and emergent coding, especially for the analysis of verb clusters (Bell et al., 2010).

5.3.2 A Five-Step Approach to Content Analysis

The five-step approach to Content Analysis adopted in this study is fairly standard (Robson, 2002) (Krippendorf (1980) offers a variation on this approach, which is presented at Appendix 5.2).

Step 1: Select the Sample/Group

The student group selected for this study is not conceived of as a sample, random or otherwise, from a larger population of MIS students. The size of the OLD group, 17 students, is not untypical for such Content Analysis studies. For instance there are 13 students in Fahy's study and 11 in Garrison's (Fahy et al., 2001, Garrison et al., 2001).

Step 2: Define Recording Unit

Following Fahy et al. (2001), the recording unit chosen for this study is the sentence.

Step 3: Define Categories and Codes

The study, as mentioned above, adopts a prescriptive approach to the generation of coding categories. Entity modelling, a technique borrowed from the field of Information Systems (Chester and Athwall, 2002), was used to systematically develop a high level, graphical overview of the coding structure *prior* to coding of the data (Appendix 5.4).

Step 4: Test proposed categorisation scheme against a small subset

Small data subsets were used to test the categorisations. This offered, among other things, the opportunity to evaluate possible coding schemes and choices of recording units. As a result, it was decided to adopt the sentence as the recording unit.

Step 5: Conduct analysis

The research is designed as a small scale multiple case study, consisting of four cases. There are two Hypermedia cases (referred to as Hypermedia_COGITASK1 and Hypermedia_COGITASK2) and two Modelling cases (Modelling_COGITASK3 and Modelling_ COGITASK4). The approach taken to the analysis takes the following lines:

Analyse Hypermedia Case Study 1 (Hypermedia_COGITASK1)

Analyse Hypermedia Case Study 2 (Hypermedia_COGITASK2)

Compare the two cases. Draw provisional conclusions.

Analyse and compare the Modelling case studies 1 & 2 (Modelling_ COGITASK3&4)

Compare the Modelling results against the Hypermedia cases.

Compare the above against the COGITASK data in Chapter 4.

This approach follows the general guidelines set out by Yin (1994).

Triangulation

The data was first analysed using a latent content analysis approach, taking the sentence as the recording unit. A second, manifest content analysis, using words and word clusters, was also conducted. This was triangulated with the first to increase reliability.

Quantitative and Qualitative methods

Quantitative analysis of content analysis studies range from the use of quasi experimental designs and complicated multilevel statistical procedures to more simple descriptive ones (De Wever, 2007: 436; Ya-Ting et al., 2007a). The quantitative analysis in the current study was conducted using the simple, descriptive techniques of exploratory data analysis (Erickson and Nosanchuk, 1988). The quantitative analysis is complemented throughout by a qualitative analysis which focuses on the text itself.

5.3.3 The Codebook

The purpose of the codebook is to facilitate consistency and reliability in coding. The codebook contains details about each code such as in the extract below, the name of the coded item, the code, a detailed description, examples and indicator words or phrases (Appendix 5.1).

Coded Item Name	**Code**	**Description**	**Example(s)**	**Indicator Words**
Task_Difficulty	T01	A task is perceived to be difficult or not.	*At first I thought this to be a formidable challenge, having little knowledge in this area* *I found the task that beset our group to be quite a challenge.*	Difficult, challenging, easy,

The codebook also provides rules and guidance on how codes are to be assigned to a recording unit, including guidance on difficult cases. Examples of such rules are:

'Rule 3: Always code the main point of the statement.'

'Rule 5: Code in context'

The codebook benefited greatly from trials with small data subsets (The reader may find it useful, at this stage, to consult the codebook at Appendix 5.1 for a detailed description of general definitions, categories and rules for coding and cross checking).

5.3.4 Methodological Issue: Trustworthiness of the Coding Scheme

The trustworthiness of the coding scheme is a key issue in Content Analysis (Rourke et al., 2001; De Wever, 2006; Rattleff, 2007).The following actions were taken to increase the trustworthiness of the coding scheme:

The sentence has been chosen as the recording unit because, being syntactically defined, its definition is relatively reliable. Given that the sentence also provides a meaningful context for the code, the sentence is likely to be more validly interpreted than, for instance, a single word used as the unit of analysis. For instance, the word ‘feel’, occurring in isolation, might be assigned to the code P01, which records ‘individuals’ issues and feelings’. When, however, the word is considered in a context such as the following:

> *I feel our end result was exactly the type of product that .... our client was looking for* [Frank]

It becomes clear that in this context the word has little to do with ‘feelings’ or ‘emotions (Rule 5). ‘Feel’ in this context is being used as a synonym for ‘think’. As the main point of the statement (Rule 3) concerns achieving the task objective and not any emotional response, the text is coded as **T03** ‘End Result’.

Modifications to coding categories and the reliable assignment of codes indicated by the trials were implemented. For instance, the use of cross-check queries for every batch of 50 statements is designed to improve the reliability of the codes assigned (Rourke et al., 2001). Furthermore, two approaches to content analysis, namely, latent and manifest, have been triangulated.

As a result of the above the code-recode reliability of the study is reasonably high, namely, 0.85 (De Wever, 2006).

5.4 Analysis of Student Reflections and Perceptions

5.4.1 Task

This section presents empirical data relating to students' perceptions of, and reflections on, their own strengths and weaknesses (Research Question 2). The discussion avails of Flavell's three-factor metacognitive framework – Task, People and Strategy. We turn, first, to the Task-related aspect of metacognition.

Table 5.3: Frequencies (f) and relative frequencies of 586 student statements classified by Metacognitive Factor.

Metacognitive Factor	(f)	% of Total
Task	118	20%
People	98	17%
Strategy	338	58%
Other	32	5%
Totals	586	

When students are asked to reflect on the most important factors determining their performance we can see from the above table that some 20% of all statements are reflections on Task-related issues. This is broken down (for the Hypermedia data only) into the task-related items in the table below.

Table 5.4: Frequency distribution of 45 Task-related statements, classified by Task-related Item (Hypermedia only).

Task-Related Item	(f)	% of Total
End Result	19	42%
Tool usefulness	17	38%
Task_Difficulty	4	9%
Task_Description	3	7%
Tools_Ease_ofUse	1	2%
Other_Context_Task	1	2%
Totals	45	

At the top of the list some 42% of statements relate to 'achieving the end result' and some 38% are comments on the usefulness of the tools. The table below shows the frequencies when the Modelling data is added.

Table 5.5: Frequencies (f) and relative frequencies of 118 Task-related statements cross classified by Task-related Item and Tool Category

	Hypermedia		Modelling		Totals	
Task-Related Item	**(f)**	**%**	**(f)**	**%**	**(f)**	**%**
Tool usefulness	17	38%	39	53%	56	47%
End Result	19	42%	22	30%	41	35%
Task_Difficulty	4	9%	5	7%	9	8%
Task_Description	3	7%	5	7%	8	7%
Tools_Ease_ofUse	1	2%	2	3%	3	3%
Other_Context_Task	1	2%		0%	1	1%
Totals	45		73		118	

Comparing Hypermedia and Modelling cases, two items remain the same but their order has been reversed. The question of tool usefulness is discussed fully in the next chapter. For the moment we note that a key issue of interest to these students is achieving the end result. Further confirmation of this is to be found in the table below, where students reflect on their key strengths.

Table 5.6: Frequencies (f) and relative frequencies of 66 Evaluation-type statements cross classified by Key Strength and Tool Category.

	Hypermedia		Modelling		Totals	
Key Strength	**(f)**	**%**	**(f)**	**%**	**(f)**	**%**
End Result	16	50%	17	50%	33	50%
Teamwork	9	28%	4	12%	13	20%
Planning Control	3	9%	0	0%	3	5%
Organising	2	6%	1	3%	3	5%
Tool usefulness	1	3%	8	24%	9	14%
Individual Issues	1	3%	0	0%	1	2%
Other	0	0%	4	12%	4	3%
Totals	32		34		66	

When we restrict the analysis to those statements that refer only to evaluating task performance (referred to as Evaluation-type statements) we note that the achievement of the end result is not just an issue of interest; it is perceived as the key strength, identified by students in 50% of their statements. They characterise this strength as succeeding in producing an artefact that works.

> *I think our group accomplished the task as best we could using the model of management and customer orientation that we had* [Frank].
>
> *I am delighted with the outcome of our homepage* [Maura].

The % of statements which highlight achieving the end-result as the key strength is identical (50%) in both the Hypermedia and Modelling cases – which suggests a certain uniformity of response.

Interpretation

The repeated emphasis on achieving the end result may well be related, in the first instance, to the results-oriented nature of IT work. Secondly, the technical nature of the tasks in the workplace – where there are in fact 'right' and 'wrong' answers – often leads to performance evaluation, measured by end results.

The view students express here corroborates, partially, the findings in Chapter 4, which provides evidence that students, generally, *do* achieve the end result – they do produce artefacts that work. However that is not 'the whole story'. A more accurate evaluation of the end result, based on the evidence from Chapter 4, is that while their artefacts, by and large, *work,* they frequently lack professional finish. An awareness of this shortcoming is not, however, reflected in the comments of the students. In this respect, at least, students' metacognitive knowledge may be somewhat deficient.

5.4.2 People

Turning from the Task factor, we now look at the People-related aspect of metacognition,

When students are asked to reflect on their performance 17% of statements, in Table 5.3 above, are reflections on people-related issues. This is broken down, for the Hypermedia data only, into issues relating to other people and issues relating to themselves as individuals.

Table 5.7: Frequencies (f) and relative frequencies of 59 People-related statements cross classified by People-related Item and Hypermedia COGITASK.

	Hypermedia COGITASK1		Hypermedia COGITASK2	
People-Related Item	**(f)**	**%**	**(f)**	**%**
Teamwork	**25**	60%	**10**	59%
Individual Issues	**17**	40%	**7**	41%
Totals	42		17	

It is to issues relating to others, rather than to themselves, that students mostly refer. For instance, 60% of the statements in Hypermedia_COGITASK1 and 59% of statements in Hypermedia_COGITASK2 relate to teamwork.

Our "team" worked very well, everyone was prepared to listen to others ideas and to participate in the discussion [Hilary].

I found that working in a group makes the job a lot easier as "brain storming" leads to a multitude of good ideas [Kevin].

Comparing Hypermedia and Modelling cases, in the table below, we note that in both the percentage of statements (59%) focusing on teamwork is identical, again suggesting a uniformity of response.

Table 5.8: Frequencies (f) and relative frequencies of 98 People-related statements cross classified by People-related Item and Tool Category

	Hypermedia		Modelling	
People-Related Item	**(f)**	**%**	**(f)**	**%**
Teamwork	35	59%	23	59%
Individual Issues	24	41%	16	41%
Totals	59		39	

Returning once more to the Evaluation-type Statements of Table 5.6 we note that students identify ‘Teamwork’ in 20% of their statements as the next most important key strength after achieving the end result.

Interpretation

These data provide fairly clear evidence that when these students assess their people-related strengths they do so in terms of collective rather than personal strengths. Teamwork is a key strength which they attribute to themselves and something that they value (cp. Kay, 2006).

However the focus on *other* people is accompanied by a lack of focus on individual issues. This may be attributable to an unwillingness to highlight their individual shortcomings in public, reluctance to speak of their strengths lest they are thought arrogant by their peers or a blindness to their own weaknesses or, more likely, a combination of all of the above (Schraw, 1998).

The importance of such personal reflections on beliefs, goals, motivation and capability is now recognised but so also is the widespread absence of such self-knowledge among students (Pintrich, 2002).

If teamwork is perceived as an important strength, then a lack of technical capacity is perceived as their main weakness. By this students mean that they have insufficient skills or experience of the software tools that they use to build their artefacts.

> *No-one in the group was familiar with HTML or Dream weaver so we chose to do our website in Microsoft Word* [Maura].
>
> *As our team had four (4) members, but none had any web-design expertise, a full "division of labour" approach into content and design teams was not possible* [Kevin].

The table below, which summarises the tool characteristics most commented on – provides further confirmation that students perceive a dearth of technical capacity to be an important weakness. Overall about one in ten students (9%) point to technical weakness as an important issue.

Table 5.9: Frequencies (f) and relative frequencies of 80 statements describing the Tool characteristics most often commented on cross classified by Tool Characteristic and Tool Category

	Hypermedia		Modelling		Totals	
Tool Characteristic	**(f)**	**%**	**(f)**	**%**	**(f)**	**%**
Features	7	29%	30	54%	37	46%
Description	5	21%	10	18%	15	19%
Effects	4	17%	8	14%	12	15%
Usefulness	3	13%	4	7%	7	9%
Tech. weakness	4	17%	3	5%	7	9%
Miscellaneous	1	4%	1	2%	2	3%
Totals	24		56		80	

The fact that students point to a lack of technical capacity is an unexpected result, given that the majority of these students work in IT and are familiar with software tools. And yet the student perception is in a way consistent with the findings in Chapter 4. There it was reported that students perform worst on the Functionality feature – that section of the task which requires them to apply technical expertise.

Students characterise their problem as a lack of technical knowledge. It is, however, more likely to be an underdeveloped ability to apply what they already know to authentic critical thinking tasks and contexts (cp. Sternberg, 1998; Mayer, 1998).

One possible explanation of students' underdeveloped ability to apply their knowledge is that students often learn their IT skills in decontextualised mastery training programs which focus on mastering software tool features rather than applying them to real-life situations (Mayer, 1998). At any rate, possession of knowledge without the ability to apply it skilfully is a persistent finding in the learning sciences (Schraw, 1998).

A more interesting finding perhaps is the fact that students do not *distinguish* between a lack of knowledge and an inability to apply it. This is perhaps telling us something about their metacognitive awareness – an issue we deal with more fully below.

Students interrelate their strengths and weaknesses. Thus, teamwork – already identified as one key strength – is vital to achieve the end result – another key strength.

> *The design layout was a result of collaboration between all team members and the multitude*
> *of different ideas made the completion of the web page possible* [Maura].

Teamwork is also good for counteracting the worst effects of technical deficiency – their perceived key weakness.

> *Overall, I learned that – in the absence of relevant design skills – collaboration and all members pulling together made the whole thing possible* [Kevin].

5.4.3 Strategy

We now turn to the Strategy-related aspect of metacognition.

Students are aware of the importance of strategies in critical thinking. For instance, from Table 5.3 above, 58% of the statements relate to strategies. The strategies can be cognitive or metacognitive. Two examples follow:

> The first statement describes a cognitive strategy. It explains the reasoning behind the choice of the entity 'customer' as the central focus for the web site.
>
> *A key element in our design was always the customer, and what we could do make the experience of using the site easier for the user* [Anthony].

The second statement points to a metacognitive strategy,

It [i.e., working on the COGITASK] *has also given me a very useful insight into time management* [Joanne].

The breakdown between cognitive and metacognitive strategies is shown in the table below.

Table 5.10: Frequencies (f) and relative frequencies of 338 Strategy-related statements cross classified by Strategy Type and Tool Category

	Hypermedia		Modelling		Totals	
Strategy Type	**(f)**	**%**	**(f)**	**%**	**(f)**	**%**
Cognitive	92	62%	156	82%	248	73%
Metacognitive	56	38%	34	18%	90	27%
Totals	148		190		338	

From the table above it can be seen that almost three-quarters (73%) of the strategy-related statements focus on cognitive strategies, whereas only slightly more than one quarter (27%) refer to metacognitive strategies. The data indicates that students are less aware of metacognitive than cognitive strategies.

This underdeveloped metacognitive awareness may explain, in part at least, the difficulties students encountered in the COGITASKs, described in Chapter 4 – many of which were precipitated by inadequate planning and a haste to become immersed in the construction aspects of the task. Perhaps a greater metacognitive awareness might have stimulated them to reflect less on the end result and more on the process that led to the end result. The relationship between process and end result is seldom alluded to by the students.

Underdeveloped metacognitive awareness may also explain why students misdiagnose their problems. For instance, these students, though technically more competent than most, tend to attribute their shortcomings in task performance, as we have seen, to a lack of technical skill rather than to an underdeveloped ability to apply it.

> 'We are continually surprised' writes Pintrich 'at the number of students who come to college having very little metacognitive knowledge, knowledge about different strategies, different cognitive tasks and, particularly, accurate knowledge about themselves' (Pintrich, 2002: 5/8; cp. Kwok and Murphy, 2005; Michalsky, 2007).

Cognitive Strategies

We have seen that students are less aware of metacognitive than cognitive strategies. The OLD data provides some detail on the cognitive skills which students highlight (Anderson et al., 2001, Bloom, 1956).

Remembering, Understanding and Describing

The table below shows a distribution of statement types, classified as 'descriptive' and 'analytic'[6]. A few examples of descriptive statements illustrate their descriptive nature:

I enjoyed the task very much and the sense of achievement was great [Angela].

I found the task that beset our group to be quite a challenge [Harry].

These statements simply describe. There is little attempt to analyse or critique.

[6] These categories are based on the Codebook's statement types Evaluation, Learning and Reflective. Evaluation-type statements and Learning-type statements tend to be analytical. Thus, the count for 'analytic' is the pooled count of these two statements types. Descriptive is total count for the remaining statements. These are very rough equivalences, of course, but they do give us an insight into the cognitive skills apparent in the OLD texts.

Table 5.11: Frequencies (f) and relative frequencies of 586 student statements cross classified by Statement Type and Tool Category

	Hypermedia	Modelling	Totals	
Statement Type	**(f)**	**(f)**	**(f)**	**%**
Analytic	70	89	159	27%
Descriptive	191	236	427	73%
Totals	261	325	586	

Of the above statements 73% are Descriptive and the remainder Analytic. Once again, there is a strong uniformity (e.g., 73%) between both Hypermedia and Modelling data.

The data provide evidence that students tend to *describe* metacognitive strategies rather than to evaluate their appropriateness or to reflect deeply on what they have learned from them (Kwok and Murphy, 2005). This is also consistent with the findings in Chapter 4, where, when students are faced with a cognitive task, they score highest on the descriptive aspects – most notably the Content/Knowledge feature – of the COGITASK (cp. Mayer, 1998). In this instance, when faced with a metacognitive task of reflecting on their performance they also gravitate towards the descriptive, tending to remember rather than to reflect. Thus, in this instance at least, the metacognitive tendency to the descriptive parallels the cognitive one.

Interpretation

A wide variety of explanations is possible: remembering and describing, according to Bloom, are easier to accomplish than analysing (Anderson et al., 2001; Bloom, 1956). In addition, the assessment systems in the IPA and in professional IT bodies often reward students for their ability to describe. Students learn to respond strategically.

And yet the work of an IT trouble-shooter surely requires sophisticated analytical skills, the ability to deduce the causes of problems from their symptoms? Therefore, one would have thought that these analytical skills would be highly developed in these students as a result of their workplace training. One possible explanation is that these students learn highly domain-specific approaches to very specific problems: tried and tested routines for solving printer problems, cabling problems or email problems. Such routines serve these students well as long as they encounter problems in the situated contexts with which they are familiar. However, these students are seldom exposed to the more general aspects of problem solving and thus when encountering new situations, such as the COGITASKs, can find themselves in difficulty.

Analysing

Students describe their performance in broad, general terms but frequently without either elaboration or support. This is not uncommon in other similar studies (Ya-Ting et al., 2007b; Kay, 2006). The following examples are not untypical.

In general it was a practical way for us to apply the methods we had covered in the previous class [Dearbhla].

Overall I thought this exercise put into practice the information we learned on the first day of the course [Clare].

It's very important who you have working on the project [Hilary].

One might have reasonably expected a somewhat deeper analysis in which students might have delved into their strengths and weakness or elaborated on a point in more detail. Instead students' analysis tends to remain general and broad, often indicated by expressions such as 'in general', 'overall' and 'all in all'.

The surface-level analysis is consistent with the findings in Chapter 4. When students are faced with a cognitive task, a major weakness identified there was a lack of depth in students' understanding. When students are faced with a *metacognitive* task of analysing their own performance, the students' metacognitive knowledge is also shown to lack depth. Students' capacity to reflect on their understanding, that is, their understanding of their understanding can be somewhat superficial (Sternberg, 1998). Once again, a cognitive weakness is paralleled by a metacognitive one.

Applying

When students refer to cognitive skills, 'applying' is the one most often referred to, as shown in the table below.

Table 5.12: Frequencies (f) and relative frequencies of 248 student cognitive strategy statements cross classified by Cognitive Strategy Type and Tool Category

	Hypermedia		Modelling		Totals	
Cognitive Strategy Type	**(f)**	**%**	**(f)**	**%**	**(f)**	**%**
Applying	40	43%	85	54%	125	50%
Other	52	57%	71	46%	123	50%
Totals	**92**		**156**		**248**	

This can be further broken down as follows

Table 5.13: Frequencies (f) and relative frequencies of 125 statements referring to 'Applying' cross classified by Application Focus and Tool Category						
	Hypermedia		Modelling		Totals	
Application Focus	**(f)**	**%**	**(f)**	**%**	**(f)**	**%**
Spcfc. Concepts	13	33%	33	58%	46	37%
Broad/Superficial	17	44%	19	34%	36	29%
Technical	5	13%	2	4%	7	7%
OTHER	5	10%	31	5%	7	29%
Totals	40		85		125	

On the positive side, 48% of the statements identify a specific concept which has been applied.

Looking at the Value Chain [concept], *we also focused on adding value to the site by delivering what the customer needed each step of the way* [Hilary]

Less positively, 38% of the reflections on application are stated vaguely in broad or superficial terms.

I found it very useful to put some of the concepts we discussed on the previous day into practice [Anthony].

The exercise was extra beneficial because it built on what we had learnt from our previous lesson [Fidelma].

Evaluating

When asked to evaluate their experience or reflect on their performance, students highlight the positives.

Table 5.14: Frequencies (f) and relative frequencies of student 586 statements cross classified by Statement Orientation and Tool Category.

	Hypermedia		Modelling		Totals	
Statement Orientation	**(f)**	**%**	**(f)**	**%**	**(f)**	**%**
Negative	10	4%	5	2%	15	3%
Positive	138	53%	116	36%	254	43%
Neutral	113	43%	204	63%	317	54%
Totals	261		325		586	

In the table above we can see that only 15 (or 3%) of the statements are negative and almost half (or 43%) are positive.

Through clearly defined objectives, good communication, and the use of the appropriate technology, the team work came naturally and the project reached a successful conclusion [Joanne].

All in all we did succeed in developing the homepage of the website, which did reflect some of the customer needs in a clear, concise way [Dearbhla].

While, on the one hand, it is important that students feel positive about what they have achieved, on the other, the statements tend to indicate that students' evaluations require more balance (Pintrich, 2002).

One might have reasonably expected that they would have weighed some of their more obvious deficiencies against some of their strengths (but perhaps this is due to a reluctance to draw attention to shortcomings which might result in negative assessment). Overall, as Mayer observes, the data suggest that students may need some guidance in their interpretation of success and failure (Mayer, 1998: 51).

The lack of an evaluative orientation is paralleled elsewhere (Kay, 2006).

Summary

In this section we have reviewed student reflections on their critical thinking performance using Flavell's Task- People- Strategy- metacognitive framework. Students perceive achieving the end result (Task) and Teamwork to be their strengths and a lack of technical capacity to be their main weakness. Students frequently reflect on the team but seldom on themselves as individuals (People). Furthermore, students are less aware of metacognitive strategies than cognitive strategies (Strategy).

5.5 Triangulating the results with Manifest Content Analysis

To this point, the study has employed a latent approach to Content Analysis. A manifest Content Analysis procedure was devised to provide a broad cross check of the results emerging from the latent analysis. This procedure, set out in Appendix 5.3, involved the generation, identification and analysis of verb clusters. This results in a frequency distribution of clusters. The approach is not unlike that adopted by Bullen and others, whereby latent variables are combined with manifest indicators (Bullen, 1998; Rourke et al., 2001: 8/15). The top ranking verb clusters are shown below:

Table 5.15: Frequencies (f) and relative frequencies of verb clusters for Hypermedia and Modelling cases

	Hypermedia		Modelling	
Verb cluster	**(f)**	**%**	**(f)**	**%**
Construct	54	12%	82	19%
Organise	52	12%	74	17%
Feel	51	12%	47	11%
Define	37	8%	15	3%
Work	36	8%	44	10%
Learn	33	8%	16	4%
Achieve	28	6%	10	2%
Design	27	6%	11	2%
Plan	23	5%	30	7%
Communicate	22	5%	12	3%
Decide	20	5%	31	7%
Lead	19	4%	18	4%
Present	19	4%	31	7%
Think	15	3%	21	5%
	436		442	

Looking at the data in the table above, the consistency between the Hypermedia and Modelling cases is apparent. For instance, the top three verb clusters in the Hypermedia category are the same as the top three verb clusters in the Modelling category. They are also ranked in the same order. The relative frequencies of each cluster do vary somewhat from category but are, in general, fairly consistent between categories. All in all, this data suggest a plausibly uniform set of issues of interest, preoccupations and reflections.

‘Construct’-words are the words with the highest frequency. ‘Construct’-words include words such as ‘make’, ‘create’, ‘build’ and ‘assemble’. Some 19% or almost one-fifth of the words in the Modelling cases, for instance, are ‘construct’-words. They give us some insight into the Task-related aspect of metacognition. The frequency of ‘construct’-words highlights the importance that students attach to the making of the artefact. It is also consistent with the emphasis on achieving the end result, a perceived key strength which students identified in the earlier analysis.

The emphasis on construction is in contrast to the much lower frequency of ‘plan’-words. For instance, in the Hypermedia cases 12% are ‘construct’-words but only 5% are ‘plan’-words, in the Modelling cases 19% are ‘construct’-words but only 7% are ‘plan’-words. In each case ‘construct’-words occur more than twice as often as ‘plan’-words. These data give us some insight into the Strategy-related aspect of metacognition and corroborate our earlier findings which strongly suggested that students are more preoccupied with ‘doing’ than with planning – a tendency documented elsewhere (Michalsky, 2007; Sternberg, 1998).

‘Organise’-words, include words such as ‘manage’ ‘divide’ ‘allot’. The high % of ‘organise’-words indicate that students are aware of the necessity of this metacognitive regulatory process. Planning, also a regulatory process, in contrast, accounts for, as we have already noted, only 5% of the frequency distribution. This finding suggests that students are more aware of the importance of organising than they are of planning. One possible explanation is that the regulatory process of organising is less abstract than the process of ‘planning’. For instance, in the field of information systems, this might involve organising tangible objects, such as PCs and printers, allotting tasks to specific people and allocating software tools on a network. All of these are tangible activities.

As regards the People-related aspect of metacognition, 'lead'-words and 'communicate'-words suggest that students value learning when it is a social activity. This is consistent with the earlier finding relating to teamwork.

Thus, this brief Manifest Content Analysis provides a succinct confirmation of emergent findings in relation to the perceived importance of end results, the lack of emphasis on planning, and, to a lesser extent, the importance of teamwork. By and large, the congruence between the latent and manifest approaches is reassuring and indicative of the trustworthiness of the Content Analysis overall.

5.6 Chapter Findings, Research Question and The Critical Thinking Framework

Immediately below, the findings are interpreted in the context of the theoretical framework and then summarised in a table designed to highlight the students' perceived strengths and weaknesses, and how these relate to the theoretical framework.

5.6.1 Constructive

In the student statements a lot of emphasis is placed upon the constructive aspects of the task. Students focus on the importance of achieving the end result and the importance of teamwork in bringing this about. A lack of technical skills is also perceived by them as a weakness (though this might be disputed). Perhaps, however, the importance of achieving the end result is emphasised at the expense of analysis, process and metacognitive issues.

This ties in well with the corresponding findings at the end of the previous chapter where students created artefacts that worked but were not well finished.

5.6.2 Cognitive

In the text of their narratives evidence of higher order cognitive skills such as applying, analysing and evaluating is visible but evidence of lower order cognitive skills such as remembering and describing is more common. Consequently, the students' accounts of their performance tend to be more descriptive than analytical. However, they do recognise the importance of being able to apply concepts. While students can apply higher order cognitive skills it is clear that they have difficulties with them. Furthermore, student statements about their experience often lack depth.

These findings parallel the corresponding findings at the end of the previous chapter, where students perform less well on indicators of depth.

5.6.3 Metacognitive

Student assessment of their successes seems fairly accurate and, likewise, they show a reasonably good understanding of weaknesses and their causes. Moreover, their metacognitive awareness of the importance of other people, teamwork and of cognitive strategies is also reasonably strong.

Despite the above, students' metacognitive knowledge and awareness is generally under-developed. Students can be somewhat blind to their own misconceptions and weaknesses or misdiagnose their causes. Their metacognitive knowledge also appears to be somewhat lacking in depth and thus their accounts of their own performance often tend towards the superficial.

Knowledge of metacognitive strategies is also underdeveloped. When judging their own performance students often focus on the end result without looking at the process that led to the end result. This suggests a certain lack of awareness of the processes of metacognitive control such as planning, organising and checking.

While the metacognitive aspect is not considered in the previous chapter, this chapter ties in quite well with other findings there. For instance, the underdeveloped metacognitive awareness, described here, may well explain the inadequate planning reported in the previous chapter. Similarly, metacognitive weaknesses, discussed in this chapter, have parallels with certain cognitive weaknesses such as lack of depth and the tendency to describe rather than analyse, reported in the previous chapter.

5.6.4 Knowledge

Student statements indicate that students learn both domain-specific and general knowledge. Domain specific concepts include 'the value chain', 'customer focus', 'customer needs analysis' and technical knowledge such as graphics and websites. General knowledge most often refers to 'know how', learning how to put ideas and concepts into practice. It also includes time management. The application of their knowledge can be overly broad and superficial, a common theme throughout.

The findings are set out in tabular form immediately below

Table 5.16: Students' *perceptions* of their strengths and weakness, based on the OLD data, related to the theoretical framework	
Theoretical Framework Related Aspect	**Findings: Strengths and weaknesses, based on OLD data**
STRENGTHS	
Constructive	Strong focus on achieving the end result Teamwork is seen as a key strength. A strong orientation towards the importance of construction (rather than towards analysing and planning)
Cognitive	Students recognise the importance of applying. Students do apply higher order cognitive skills such as applying, analysing and evaluating but are better at applying lower order cognitive skills such as remembering and describing. Students are reasonably good at applying domain specific concepts. [General knowledge most often refers to 'know how', learning how to put ideas and concepts into practice. 'Putting into practice' is seen as being critical to getting meaning out of their experience]
Metacognitive	Their general assessment of their successes and the reasons for it is fairly accurate. Have a reasonably good knowledge of the importance of other people and teamwork Have a reasonably good knowledge of the importance of cognitive strategies
Knowledge	Students learn both domain-specific and general knowledge. Domain-specific concepts include value chain, customer focus and analysis of customer needs, technical knowledge such as graphics and websites. General knowledge most often refers to 'know how', learning how to put ideas and concepts into practice. 'Putting into practice' is seen as being critical to getting meaning out of their experience.
WEAKNESSES	
Constructive	Perhaps the importance of achieving the end result is emphasised at the expense of analysis, process and

	metacognitive issues. Lack of technical skills
Cognitive	The application of their knowledge can be overly broad and superficial. Can apply higher order cognitive skills but have difficulties with them Evaluation accounts tend to lack balance
Metacognitive	Students' metacognitive knowledge and awareness is under-developed. Their metacognitive knowledge appears to be somewhat lacking in depth, their accounts of their own performance often tend towards the superficial (the metacognitive tendency to the superficial parallels the cognitive one). Students can be somewhat blind to their own misconceptions and weaknesses or misdiagnose their causes Knowledge of metacognitive strategies is underdeveloped Underdeveloped processes of metacognitive control such as planning, organising and controlling. Strong tendency to describe their experience (e.g., their metacognitive strategies) rather than reflect on it or analyse it (the metacognitive tendency to the descriptive parallels the cognitive one).
Knowledge	The application of their knowledge is somewhat superficial

5.7 Chapter Summary

The previous chapter focused on the constructive, cognitive and knowledge aspects of the framework for critical thinking. This chapter, dealing with students *perceptions* of their own strengths and weaknesses, has focused on the metacognitive aspects of critical thinking. The chapter presents empirical evidence to show that when students reflect on their performance they consider achievement of the end result and teamwork as their main strengths, whereas inadequate technical capacity is perceived as an important weakness. Broadly speaking, students are more aware of goal achievement than process, more aware of cognitive than metacognitive strategies, more aware of team failings than individual failings and more adept at lower order than higher order skills. The chapter concludes by summarising the relationship between the chapter's findings (perceived strengths and weaknesses) and the theoretical framework. The findings are broadly consistent with those which emerged from Chapter 4. In the next chapter these findings are brought together and related to underlying tool-based mechanisms and ultimately their implications for teaching tool-based critical thinking.

5.8 Reflection

Subjectivity revisited

Metacognition has been an important theme of the chapter. Here I reflect on both the general and specific strategies I have adopted for this data analysis task.

Generally speaking, from the researcher's point of view the OLD transcripts are messy. They contain unfinished sentences, inappropriate punctuation, unclear expression and some ambiguity. The analysis of the OLD transcripts presents problems which ultimately revolve around uncertainty, its interpretation and the subjectivity of that interpretation.

I tried to deal with subjectivity by employing quantitative methods, analysing data systematically, presenting it in easy to understand tables, using simple statistics – counts and frequencies – then exploring interesting data features, comparing numeric and textual data, and, finally, making some attempt to interpret it. Although I am formally trained in statistics and have taught courses on classical statistics, the approach here can be thought of as a 'rejection' of those uses of classical statistics that summarise data without offering much in the way of exploration so that in the end, one feels, the statistics tend to occlude rather than elucidate meaning.

The simple approach I take here is an attempt to draw out meaning and share that with the reader. But it is only one meaning. It is selective. This is inevitable since I focus on that which seems interesting to me. However, the use of mixed methods helps me to avoid the worst excesses of idiosyncratic interpretation since it allows the qualitative to inform the quantitative approach and vice-versa.

My experience of using the Content Analysis technique exemplifies some of these points in a more specific way. I chose the approach of Content Analysis, a partially quantitative technique, as a way of putting some order on uncertainty. In hindsight, I see this as a characteristic move for me – a return to familiar territory.

I was to learn, however, that Content Analysis in itself can be highly subjective. Some examples, in my own work, where this subjectivity arises are: the choice of the type of Content Analysis itself, the choice of the unit of analysis (sentence, etc.), the choice of categories, the assignment of an item to any given category. That amounts to a lot of subjectivity – none of which is conveyed by frequency distributions.

I tried to handle some of these difficulties by triangulating one content analysis method with another, by selecting the most definable unit of analysis – the sentence – and by developing a codebook which contains rules, procedures and indicator words for the assignment of codes. I computerised all of the above in a database and I wrote a set of queries which could identify possible coding mismatches.

I realise now, as I reflect, that this was a lot of work and that it shows a strong desire to get to 'the truth'. That is commendable. However, I have grown to learn that it is important just to be able to live with subjectivity, and to accept it as the nature of things, without trying to overly structure it, and of course to moderate all claims that one makes.

CHAPTER 6: EIGHT POSSIBLE CRITICAL THINKING EFFECTS AND RELATED TOOL MECHANISMS (RESEARCH QUESTION 3)

6.1 Introduction and Purpose

The previous two chapters produced findings (consolidated in Appendix 6.1), based on objective and subjective data, relating to student strengths and weaknesses in critical thinking (Research Questions 1 and 2). The purpose of this chapter is to explore, in detail, how tool-based mechanisms may contribute to explaining these findings (Research Question 3, below).

Table 6.1: Research Question 3
3. Mechanisms and conditions By what mechanisms, and under what conditions might tool use enable/facilitate critical thinking?

Drawing heavily on the OLD perceptual data and using example statements from the students concerning their critical thinking strengths and weaknesses, the chapter discusses eight possible critical thinking effects, covering all aspects of the theoretical framework: constructive, cognitive, metacognitive and knowledge.

While the primary focus of the chapter is to explain how technical mechanisms can enable critical thinking effects, it is acknowledged that such effects may also be enabled by non-technical mechanisms, such as collaborative and group regulatory mechanisms. Although such non-technical mechanisms are not directly within the scope of the study, this chapter includes a short section indicating how non-technical mechanisms and technical mechanisms may interact to enable critical thinking effects. We now consider each of the critical thinking effects, in turn. In the discussion below, in order to highlight evidence from the study, examples have been enclosed in boxes and quotations from students have been italicised (The reader may find it useful, at this stage, to consult Appendix 3.1 for a detailed description of the COGITASK).

6.2 Constructive Effects

This section, relating the discussion to the consolidated findings (Appendix 6.1) and drawing on further evidence and examples from the study, focuses on how tools can support the **constructive** aspect of critical thinking by (1) the provision of technical frameworks and (2) supporting the processes of analysis and synthesis.

6.2.1 Tools Can Provide a Technical Framework Which Scaffolds Construction

In the construction of artefacts, tools may provide a technical framework to help students construct knowledge out of experience with authentic tasks. The technical framework includes predefined structural framework(s) and predefined procedural framework(s).

Thus, in the case of hypermedia, the homepage-page-object-structure is an example of a predefined structure. This structure provides a structural framework or shell for the student constructing a website. Similarly, the predefined database-table-record-field-structure provides a framework to scaffold the construction of a database. The book-sheet-cell-structure provides a framework to scaffold the construction of a spreadsheet.

Such structural frameworks can act as a mechanism that helps to synthesise components of the artefact under construction into a coherent whole.

Frameworks

One student says:

Once the design was agreed, it was necessary to create a "shell" for the EIS [Kevin].

Students lean on these predefined structures to construct their models. However, in order to avail of the structural framework, students must have a conceptual framework to align to it. This, in turn, requires students to be reasonably clear on the *meaning* of each of the conceptual framework's components and how they relate to one another.

By using the model [the conceptual framework] *that we were shown on the previous day (The MBO) it* [the technical framework] *put a structure around what was needed for the EIS* [Hilary].

A 'wizard' is an example of a predefined procedural framework(s). A procedural framework synthesises construction tasks along a predefined sequence of steps or procedures. Predefined sequences encourage users to (1) consider all the conceptual framework's components (2) to impose consistent structure on the component data and (3) to execute the task in the appropriate sequence. Other examples of procedural framework(s) in *Excel* include the Pivot Table wizard, Subtotals and Consolidation. Overall, the technical framework scaffolds the construction of fully functional, 'professional'-looking artefacts.

Frameworks

Evidence from the study indicates that students are strongly oriented towards construction. Therefore it is not surprising that anything which supports that is greeted warmly.

I was amazed at what we could come up with using the Excel package [Hilary].

The end result was a very professional looking customer-centred homepage [Conal].

The tool provides a framework that allows students to get started on construction and make progress quickly. Express tools – reduced versions of the standard tool – are often useful in this regard:

We used FrontPage Express, which is a smaller version of the large Microsoft web design application, which is very easy to use [Frank].

6.2.2 Tools can Support Analysis and Synthesis

Analysis: When using tools, the technical process of analysis parallels and supports the cognitive process of analysis. *Prior* to engaging in any construction task, the task must first be analysed into its logical or conceptual components. Like the task, the tool also consists of components – not logical, but technical. Thus, in the case of tool-based tasks, conceptual and technical components must be aligned (McFarlane et al., 2000). For instance, in using a spreadsheet, each term in a formula (logical/conceptual component) must be allocated to the appropriate spreadsheet cell (technical component). The technical structuring of the task into cells parallels and reinforces the logical structuring and analysis of the task into separate logical units.

Analysis

In The Design of an Executive Information System (EIS) task, students realise that the EIS must first be broken down into conceptual components such as Key Result Areas, Indicators and Targets. These must be mapped to corresponding technical components such as workbooks, worksheets and cells. One group used a concept map at analysis stage to decompose the task into conceptual components.

We found the use of a concept diagram at the start of the exercise helped us to understand the different concepts we had to explain [Conal].

Another group was particularly earnest. They obviously recognised the importance of completing their analysis *before* moving on to construction – and did not move to the computer room before doing so:

Once this was done [the analysis phase] *we ventured to the computer room and opened up Word 2003 to create a data flow diagram, in order to plan the system as it was* [Brian].

Immediately below the first student describes the process of breaking the task down into conceptual components, and the second student describes the process of aligning the conceptual to the technical.

Having the breakdown made it a lot easier for us to decide what information was required and how it should be displaced [sic] for easy reading and access [Clare].

We then created several sheets corresponding to the Key Results Area, the objective for that KRA, the targets and Indicators [Kevin].

Synthesis: When using tools, the technical process of synthesis parallels and supports the cognitive process of synthesis. Once the task has been broken down into its logical or conceptual components, these components must be synthesised into a coherent whole by means, according to cognitive accounts, of schemata or frameworks (Greeno et al., 1996; Baber, 2006). Tool-based mechanisms may parallel and reinforce the internal schematic organisation by representing logical concepts as technical components, building links between components and synthesising them into coherent, external technical structures or artefacts (Jonassen, 2003; Jonassen and Carr, 2000). The artefact is an external representation of the degree to which knowledge has been synthesised.

Synthesis

Students fare better on synthesis than analysis, showing themselves to be strongly oriented to doing, making, building, assembling and 'achieving the result'.

One student refers to how their group

put together the data and converted the data into charts and tables [Betty].

Another remark

I found this exercise very interesting and informative as it brought together in a very practical way the information in the notes [Angela].

The emphasis in both the statements above is on synthesis: 'putting together' or 'bringing together' 'constructing' data, information and ideas.

Not surprisingly, therefore, students do well on the synthesis aspect of construction – something which is reflected in the artefacts that they create:

The final product was a well laid out tutorial with very good navigation [Kevin].

All in all we did succeed in developing the homepage of the website, which did reflect some of the customer needs in a clear, concise way [Dearbhla].

6.3 Cognitive Effects

This section focuses on how tools can support the **cognitive** aspect of critical thinking by (1) facilitating application, especially of higher order learning and by (2) facilitating the deepening of understanding.

6.3.1 Tools can Facilitate the Application of Conceptual Knowledge and Higher Order Thinking

Tool-based authentic tasks orient students as much towards conceptual knowledge and higher order learning as towards procedural knowledge.

Revisiting conceptual knowledge and higher order learning

When applying their knowledge to the Design of a Customer-Oriented website, students are obliged to return to and confront the conceptual constructs, learned earlier, about customers such as ‘customer profiles’,’ customer segmentation’, and ‘customisation’.

It was interesting to do this practical exercise after the tutorial the day before where we thought about an organisation as an entity and considered the customer’s role vis a vis the organisation [Angela].

It was also great to put into practice the theory of EIS during the development; this has given me a greater understanding of EIS [Anthony].

In both of the above statements there is sense of returning to conceptual knowledge acquired earlier. Students reflect on how the act of applying their knowledge to practical tool-based tasks encourages them to revisit some aspects of the '*theory* of EIS' learned in 'the tutorial the day *before'* and to reflect upon what these conceptual constructs *mean* in practical terms. The upbeat quotations below are in a similar vein:

I think our group accomplished the task as best we could using the model of management and customer orientation that we had discussed the day before [Frank].

[The task was] *interesting and informative as it brought together in a very practical way the information in the notes* [Angela].

The knowledge, which the technical task requires students to revisit, is conceptual: their understanding of the 'theory of EIS', 'information in the notes' and 'the model of management and customer orientation'. Thus an important benefit of the tool-based task is not that it simply requires students to become technically more proficient (i.e., improve their procedural knowledge) but that it also requires them to reconsider their conceptual knowledge.

Aside from 'applying', student statements refer to higher order thinking skills such as understanding, analyzing, evaluating. Here is a sample:

[creating the web site] *has certainly given me a greater understanding of the concept of the Value Chain and how it affects IT* [Anthony].

[prior to deciding on a website,] To *start, we analyzed the job in hand* [Joanne].

I think we did well to analyze, research and develop the prototype [Dearbhla].

a greater understanding of EIS, which could be used to evaluate or design an EIS in the future [Anthony].

6.3.2 Tools can Facilitate the Deepening of Understanding

Depth of understanding is a characteristic of higher order cognitive skills and a key requirement for critical thinking. For instance, when asked to consider the effect of a public policy initiative the critical thinker may first consider its broad national implications, next its consequences at a regional level, then at city level, and, finally, its implementation 'on the street'. In this example the critical thinker attempts to determine what the policy means by applying it to a number of vertically interconnected conceptual levels, moving from the broad to the narrow, from surface to deep, progressively analysing through the layers or levels of the problem.

In the construction of artefacts, tools can also be thought of as operating at varying levels of depth, such as – in the case of a spreadsheet modelling tool – workbook (level 1 – broadest), worksheet (level 2), range (level 3) and cell (level 4). To each of these technical levels conceptual levels can be assigned, for instance, national data might be assigned to level 1, regional data to level 2 and county data to level 3. These technical levels parallel the logical or conceptual levels of progressively deepening understanding of the representational problem (Brown, 1992).

The levelled structure of the tool invites the user to clarify *the hierarchy of levels* in which the conceptual components are ordered. Once clear on this, the use of a spreadsheet obliges the user to assign each conceptual component-level to a separate technical component-level. Components are linked in a hierarchy of levels by means of hyperlinks which can be used to drill down between these progressive levels of depth (Liu et al., 2004). For example, in an EIS the Summary Model might be assigned to the workbook (level 1), each Key Result Area to a worksheet (level 2), each Indicator to a range (level 3) and each Target to a cell (level 4). Hyperlinks are added to enforce the ordering of technical components into (progressively deepening) levels that correspond to the conceptual levels of the logical components. Importantly, the spreadsheet model requires the user to do all of the above consciously and explicitly (Ruohoniemi, 2010; Kirschner and Erkens, 2008). Thus the levelled or hierarchical structure of components in the tool complements and encourages the deep approaches to learning.

Depth

Evidence from the study indicates that students' understanding can be a little shallow. For example, in the quantitative analysis low score items are all associated with lack of depth of understanding,

This is not to say that students are unaware of the effect of tool-based tasks on deepening understanding of concepts. Although students never use words such as 'deep' or 'depth' to describe their learning, the language which they do use is nonetheless indicative of an awareness of deepening of understanding. For instance, the tool-based tasks 'forced us to focus', 'drove home what we learned', or 'refocused my mind on BPR', or 'made you think a lot more', or 'highlight[ed]' certain learning points and, ultimately, facilitated 'greater understanding'. Other examples of this deepening include:

*It definitely made me put a **lot of thought** into the EIS and into its ability to aid managers in the decision making process* [Kay].

*It highlighted to me personally, the importance of **constantly considering** … the end-user's requirements* [bold added] [Joanne].

Commenting on the difficulty of one of the tool-based tasks, one student alludes to the depth of knowledge required:

Looking at it from this prospective [sic] shows the level of detail that needs to be considered [Angela].

6.4 Metacognitive Effects

This section focuses on how tools can support the **metacognitive** aspect of critical thinking by (1) exposing weaknesses in critical thinking and (2) making critical thinking visible.

6.4.1 Tools can Expose Weaknesses in Critical Thinking

Tools facilitate, but do not guarantee the production of, certain effects. When such effects are not produced, tools expose weaknesses in all four aspects of critical thinking, constructive, cognitive, knowledge and metacognitive.

Tools expose constructive weaknesses in functionality, form and finish. Examples from the study include artefacts that don't work (functionality), inconsistencies in artefact layout (form) and, incomplete task elements such as navigation buttons (finish).

Tools expose cognitive weaknesses. Examples from the study relate to a lack of skill in applying knowledge as well as to a lack of depth in application. This, in turn, provides insights into gaps in understanding or gaps in procedural knowledge.

Tools expose weaknesses in procedural knowledge, often signalled by the beeping of error messages or the blank screen of the student who is 'stuck'. Similarly, such tasks often expose misunderstandings and imprecision in conceptual knowledge. On more than one occasion students in the study are shown to be *actually* confused about terms they can *theoretically* define. For instance, at the outset of the Design of an Executive Information System (EIS) task students had little difficulty in defining terms such as 'objective', 'indicator' or 'target'. In virtually all groups, however, when students were required to operationalise these terms, by means of a tool, the confusion was apparent. It was clear that students were unsure as to what these terms in fact *mean* in practice.

The weaknesses described above, and the accompanying error messages, invite the student to activate his/her metacognitive knowledge (the student becomes aware that 'something is wrong') and metacognitive control (the student does something about it) (cp. Downing, 2009). Thus, tools expose metacognitive weaknesses when the student neither reflects on the error message nor takes steps to regulate the situation.

Metacognitive knowledge and control

Examples of metacognitive knowledge appear immediately below. The statements reflect on issues relating to the metacognitive factors task, people, and strategy, respectively.

I found the task that beset our group to be quite a challenge [Harry].

While my initial thought on doing this exercise was one of apprehension I thoroughly enjoyed the practical aspect of creating an EIS [Fidelma].

Graphics and pictures are a useful way to get the point across to the student or target audience. [Karl].

Weaknesses in metacognitive control, such as failures to regulate the task, become apparent in the design *process* that surrounds the creation of any tool-based artefact. Furthermore, since tools preserve the artefact in various stages (versions) of construction they provide feedback both on the process and on the skill with which it is regulated (metacognitive control). Weaknesses in metacognitive control are exposed in this electronic record (Stahl et al., 2005).

What I learned was that proper planning and design, relevant information and user friendliness were the key areas that needed to be looked into when creating the EIS [Kevin].

Developing the EIS showed the importance of proper planning of the EIS to create a system which has the ability to access relevant information in a user friendly manner [Conal].

6.4.2 Tools can Make Critical Thinking more Visible

Tools externalise thinking, such as when humans resort to pen and paper, to represent problems that they cannot solve in their heads.. Since their thinking is externalised in representations, such as the electronic artefacts of this study, their thinking is visible (Baber, 2006). This is important since the study's findings indicate that students can be somewhat blind to their shortcomings – a rather human failing. Another way of describing this process might be to say that tools make the abstract concrete and, therefore, visible. For instance, when an abstraction such as a 'vision of customer service' assumes a 'concrete' form in an organisation's website, the 'vision' becomes visible.

Externalisation and Visibility

For instance, in an authentic task such as the Re-engineering of a Business Process, one student, on completion of the process modeling, notes,

I found the exercise enjoyable and made *aware to me that once you put a process down on paper it is phenomenal to* ***see*** *the amount of resources that are used and in some cases unnecessarily* [Frank].

Students use the word 'see' frequently to describe their metacognitive knowledge in terms of growing awareness and learning:

The socio-technological model was clearly ***seen*** *in the sense of people (our team) working together using technology (MS Word) to achieve our task (creation of the web page)* [bold added] [Kevin].

We had been doing labs at the web design course the week before which were somewhat confusing, but this project help me greatly as I could ***see*** *the theory being put to a practical use* [bold added] [Angela].

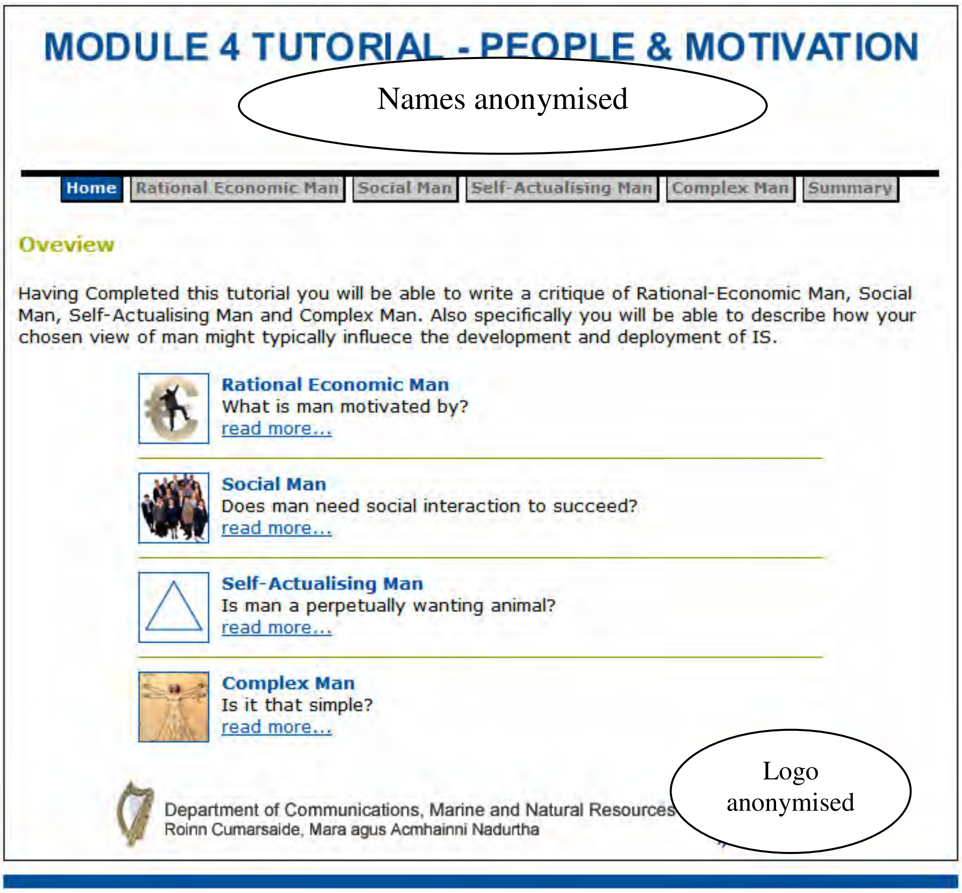
In each of the three statements above the tool helps students see the 'amount of resources' a process consumes, or to see the meaning behind a conceptual model or to see the practical implications of a theory. In all cases students are pointing to how tools make thinking more visible.

Much of the students' critical thinking (such as the processes of analysis and synthesis) could be seen *at a glance* by looking, for instance, at the artefact's homepage. On the one hand, the components of the homepage are a reflection of the way the web design task has been analysed; on the other, the homepage is the overarching mechanism where components, related to one another, are synthesised. Thus, the homepage offers an overall perspective or visible summary of the critical thinking contained in the artefact.

Homepage: visibility of thinking

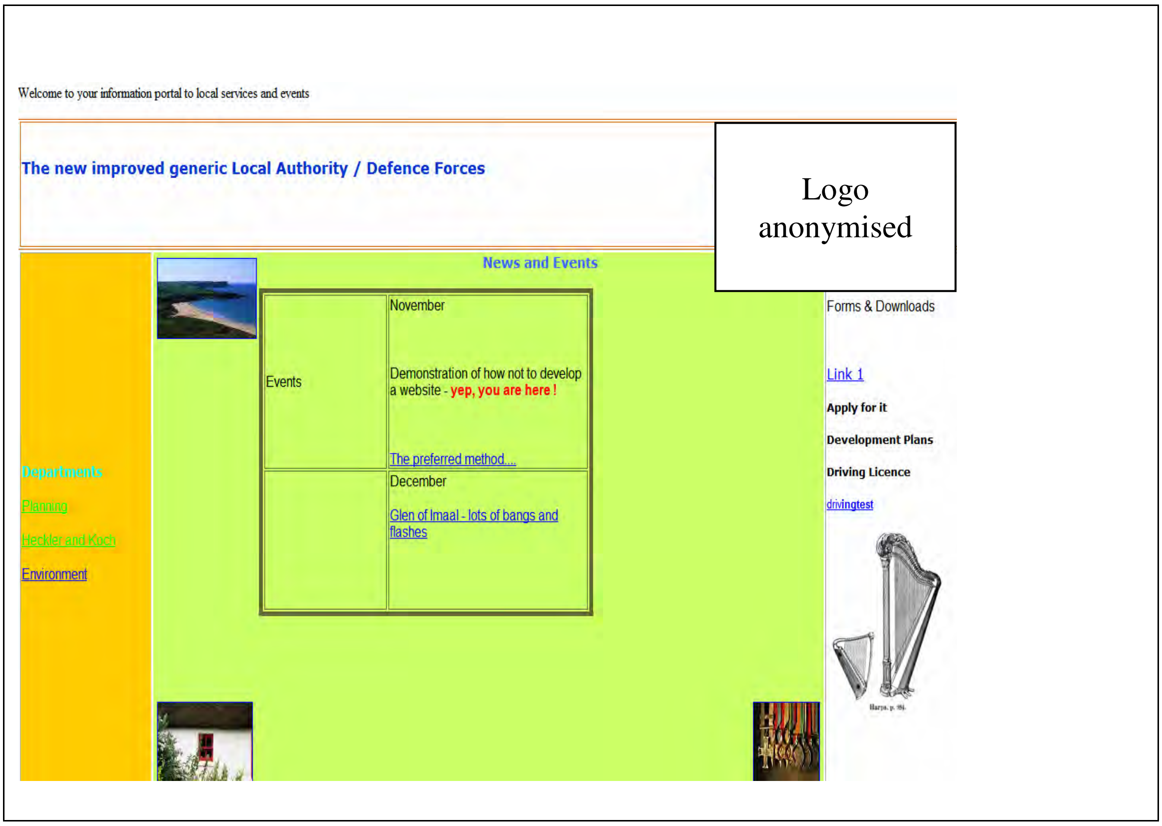
Two homepages are contrasted below. The appearance of the first is clear, containing four visible technical components, centre of the page, corresponding to important conceptual components.

Fig. 6.1: An example of a visibly well-constructed student homepage



In contrast, the appearance of the second homepage in Fig. 6.2 is confused:

Fig. 6.2: An example of a visibly poorly-constructed student homepage



The first homepage gives a clear and visible indication both of analysis – students have decomposed the problem into four conceptual components – and of synthesis – they have *consciously* related, by means of menu options, one technical component to another.

In the second the lack of clarity of the structure is indicative of a more uncertain analysis and understanding; nor is there any real pulling together of key ideas. All of this is made visible at a glance, more or less.

The examples show how a tool mechanism can provide a visible indication of the critical thinking underneath it. One student speaks of tools providing a 'visual over*view*' of one's thinking and the defects in it:

Using Excel was very good as it gave a visual overview of the links between the different sections and it showed up very quickly if there were parts of the system which would not work [Frank].

The effect is fourfold: it makes the overall synthesised structure visible (overview); it highlights links between components; it makes visible or 'shows up' defects; and, finally, it does all this 'quickly'.

How tools make thinking visible might be summarised in the words of one student:

Between the four of us I think we understood the concept behind the EIS and this ***shone through*** *in our prototype* [bold added] [Donal].

Externalisation and visibility of thinking are only partly-mediated by tools. They are also partly mediated by other non-technical mechanisms such as collaborative mechanisms (Stahl et al., 2005), a point discussed in the separate section below, 'Collaborative Effects and Tools Effects'.

6.5 Knowledge Effects

This section focuses on how tools can support the **knowledge** aspect of critical thinking by (1) facilitating the natural acquisition of knowledge and (2) by facilitating meaning-making.

6.5.1 Tools can Facilitate the Natural Acquisition of all Knowledge Types

In the case of authentic tool-based tasks, such as those in this study, factual, procedural and conceptual knowledge, general or domain-specific, are acquired naturally. This means that knowledge is acquired (1) through application to meaningful, authentic tasks, and (2) as the need for it arises, in the natural order in which the task elements are performed.

Authenticity

Tools, as we noted above, facilitate access to the authentic world of work. In the study, students value the opportunity that tools provide to engage in authentic, meaningful, collaborative activity.

It makes the learning more true to life and helps to identify what you are using everyday and puts a structure on the day to day running of the projects [Hilary].

Working within the team in whatever role gives an insight akin to the real life people met on real projects while letting you see the team dynamic and what each person can bring to the process at hand [James].

The natural order of the tool-based task elements dictates the sequence and phases of the learning. For instance in the case of an authentic task like the design of an EIS, in phase 1 much of the leaning focuses on conceptualising the problem and aligning that conceptualisation to the overall tool framework and functionality. In phase 2 learning focuses on data analysis and the use of what if and goal-seeking tools. In phase 3 the focus of learning is more on modeling and prediction and the use of tools such as macros and scenarios.

Each ‘piece’ of knowledge is learned at the natural time, in its natural order, with a view to accomplishing an authentic task.

Acquiring knowledge naturally

Among the specific items of procedural knowledge which students in the study report that they have acquired are: ‘how the *Microsoft Word* hyperlink function enables the setup of a realistic webpage’, ‘the concept of 'conditional formatting', ‘tools necessary for charting’, ‘the use of formatting’, ‘the use of navigation [novel concept of backward navigation]’, and how to generate their own ‘customised report by keying in variables and linking to external data sources’.

Others report actually learning how to use a new tool from scratch.

‘None of the group had heard of *SmartDraw’* – one student reports – but they managed to learn how to use it ‘on the fly’ in order to produce ‘professional’ data flow diagrams. ‘Despite the fact that none of [the] group had experience in any of the web creation packages’ the group still managed to learn it, when the need arose, in order to construct the web pages.

Generally students report experiences of extending their procedural knowledge.

By using MS PowerPoint, a tool I don't often use in the course of my work, this helped in broadening my knowledge of the many uses and functions of the software [Joanne].

Sometimes, nothing is added to the current state of their procedural knowledge but their knowledge is deepened in that they gain insights into potential applications of their current procedural knowledge.

Using Excel as a tool for EIS was challenging at first, but I was surprised at what you could actually do with Excel in creating the EIS [Brian].

Aside from procedural knowledge, tools also help students acquire conceptual knowledge. For one student the task

highlighted the challenges experienced by a team during system specification, design and analysis/review processes [Joanne].

For another, it highlighted the importance of

proper planning at the outsight and that the information contained thereon [Fidelma].

For a third it foregrounded

the benefits of approaching service delivery from the point of view of the customer needs [rather than from the point of view of technological sophistication] [Conal].

Tools, also, support the acquisition of knowledge in the following broader sense. The tool can be thought of as a tacit embodiment of the conceptual and procedural knowledge within any domain (Benson et al., 2008). Preston explains:

> 'a spoon embodies in its very shape aspects of our knowledge of the physical properties of liquids, and therefore is a peculiarly appropriate mediator of the interaction between individual and world in situations where this knowledge comes into play' (1998: 514).

Therefore, through the use of his tools the joiner, for example, acquires knowledge relevant to the domain of joinery: knowledge about the properties of wood, about right angles and measurement, and about aesthetics. Thus, authentic tool use helps the student internalise as his/her own knowledge framework the conceptual and procedural knowledge that the tool embodies, much like the way the child first learns to count on the external abacus before s/he learns to count 'in its head' (Baber, 2006; Vygotsky, 1978).

Tacit embodiment of Knowledge

Evidence from the study suggests that students are aware, at some level, that tools do embody relevant knowledge:

You don't need to be a programmer or have great knowledge to create a working system that will do all you need for this type of EIS [Hilary].

Here the student is referring to the fact that she can lean on the knowledge that is already tacitly embodied in the tool which makes the need for programming knowledge redundant.

The importance of tacit knowledge embodied in the tool is referred to again in the context of the graphical representation of data – an important characteristic of EIS's. A student comments,

I think that MS Excel was well suited for the task as it provided the tools necessary for charting [Donal].

Excel's 'Chart Wizard' helps the graphic-novices, such as these students, to represent the EIS graphically because it embodies both types of knowledge: (1) conceptual knowledge (information about chart types, scales, etc.) and (2) procedural knowledge (information about the sequence of steps to be followed).

The user avails of this tacit knowledge to help him build his chart and his own knowledge framework.

6.5.2 Tools can Facilitate Meaning-Making: 'Knowing' not Simply 'Knowing About'

Since Tools facilitate the transformation of the abstract into the concrete, it follows that tools facilitate a direct, first-hand, form of knowing.

If one is interested in learning to cycle, that is, knowing what cycling is and what it means to cycle, this can never be accomplished until it is rendered into a concrete form through the bicycle and its tool-based mechanisms: the pedals, the brakes, the handlebars. If one is interested in learning – as the MIS students in this study are – what information systems *are* and what it *means* to design such systems, thinking their way critically through that design process, then this can only be accomplished by rendering, through the use of electronic tools, information systems concepts into their appropriate, concrete form – namely, a designed information system.

If we cannot know what it means to cycle without the bicycle and if we cannot know what it means to design information systems without electronic cognitive tools, then another way of putting this is that tools help us to understand, first hand, 'what things mean'; that is, they facilitate meaning-making.

If the learner, however, does not really understand 'what things mean' then the use of tools, much like falling off the bicycle, serves, as we have seen above, to expose such misconceptions and makes visible difficulties in meaning-making.

Understanding first hand 'what things mean' is a subjective experience. This implies that the process of meaning-making results in different conceptions of meaning and different perspectives. In the appropriate environment these differences in perspective can lead to yet richer and deeper meanings.

Meaning-Making

Thus, in the task, The Design of an Executive Information System (EIS), the student gains direct first hand knowledge and experience of EIS concepts such as key result areas, indicators, targets, action plans. The tool requires the student to operationalise his/her understanding of these terms (since without such operationalisation the tool cannot be used). Thus s/he comes to know what an indicator *is*, through learning how it has to be represented and accommodated to the model. Put differently, the student comes to understand, beyond merely defining, what EIS concepts and models *mean* in practice.

Below are some examples of student statements that indicate how these tool-based tasks support meaning-making:

From doing this exercise I gained a better understanding of what an Executive Information System ***is*** [Clare].

[the tool-based task] *allowed us to build a functional prototype so we could* ***get a feel of*** *how the system would work in real life* [Conal].

It has also given me a very useful ***insight*** *into time management and customer focus*. [bold added] [Joanne].

The language here is interesting.These tasks give students an 'insight', that is, 'a deeper perception' of concepts such as 'customer focus'. They give them a 'feel' for what concepts actually mean and how they actually '*work'* in real-life. In fact, the word 'work' recurs in the context of meaning-making.

From what we learned the previous day I have a better understanding of how the socio-technical model of organisations works [Maura].

From the exercise that we undertook, I can understand how organisation analysis works [Brian].

The implication of the word 'work' above is that tools allow the user to go beyond mere static knowledge about a concept. Just as the bicycle allows the user to understand how cycling 'works', so tools allow the user to experience how a 'socio-technical model of organisations' *works'* in real life, that is, to understand what it *means* in practice.

6.6 Collaborative Effects and Tool Effects

The eight critical thinking effects described above are mediated by tools but only partly so. They are also partly mediated by non-technical mechanisms such as collaborative or group regulatory mechanisms (Stahl et al., 2005). While such mechanisms are not part of the scope of this study, two examples of how technical and non-technical mechanisms might interact are given for illustrative purposes immediately below.

6.6.1 Visibility of Thinking Through Collaboration

The metacognitive effect, '*Tools can make thinking more visible'* described above, is often at its most obvious in tasks which are both tool-based and collaborative (Shamir et al., 2008). The collaborative process, unlike the cognitive process of a single individual, is social, external and, therefore, visible.

working as part of a team any ideas put forward could be discussed and some ideas might be changed for the better while others which you thought were great ideas after discussion you could ***see*** *how they wouldn't work* [Clare].

Thus, the visible social process provides in*sights* into the regulatory aspects of metacognition, especially planning and control. For instance, at least some of the inadequacies in the student-produced artefacts, such as 'lack of finish', were precipitated by inadequate analysis and planning and a haste to become immersed in the construction aspects of the task. The tool-based process, on the one hand, makes the lack of planning visible to the observer, and, on the other, shows how the process can be collaboratively regulated.

I found that three heads was better than one and that you can have a great idea and want to run on ahead with it but when discussed with other members of the team you can ***see*** *the faults and problems you may need to change* [Clare].

Students often comment on how much they have learned from simply *looking* at the showcased work of their fellow students.

Looking at the other two teams; tutorials was also a great benefit to the day by gathering together the key points in BPR and EIS/DSS/IOS [Anthony].

I saw where other groups used SmartDraw to get data flow diagrams; it gave a better more professional finish to the work [Brian].

6.6.2 Meaning-Making through Collaboration

Similarly, the knowledge effect '*Tools can facilitate meaning-making'* is often at its most obvious in the peer interactions of tool-based collaborative tasks (cp. Guiller et al., 2008).

Meaning-Making

working with others helped develop ideas and procedures, and that, being part of a team that produced a good result gave me a great sense of achievement even though the part I played was small [Brian].

Between the four of us I think we understood the concept behind the EIS [Donal].

Thus it was being part of a group that helped students in the first group develop their ideas and it was as a result of all four members working together that the second group made sense of the task. This slightly quirky comment shows how different perspectives can enhance meaning:

From working with the other team members it quickly becomes obvious that different points of views can act like a Mind Map in that they throw up non-linear ideas which force re-evaluation of the subject matter [James].

Meaning-making is a key theme of Computer Supported Collaborative Learning (CSCL), which focuses on

> 'meaning and the practices of meaning-making in the context of joint activity, and the ways in which these practices are mediated through designed artifacts' (Koschman, 2002: 18).

CSCL emphasises how 'joint activity' enhances meaning-making; this research focuses on how tools in the creation of 'designed artefacts' enhance meaning-making.

6.7 Conditions

The cognitive tools, described here, can facilitate critical thinking effects but only under certain conditions in the learning environment (McLoughlin and Mynard, 2008). For each of the key elements of the learning environment – knowledge, assessment, community, learners and teachers (Bransford, 2002) – we point to the conditions necessary for the tools to enable critical thinking effects. This discussion is framed in Bransford's terms but it arises out of the particular research described here, with its references to deep approaches to learning, authentic tasks, self–regulation and constructivism which clearly echoes the language already used in earlier chapters. Nonetheless it is hoped that, while based on the particularities of this research, it will also serve as a more general pointer to the conditions necessary for effective cognitive tool use.

Knowledge

The curriculum encourages a balance between all aspects of critical thinking – constructive, cognitive, metacognitive and knowledge – and a balance between all knowledge types (for instance, a curriculum, grounded largely in factual knowledge, is likely to favour not critical thinking but learn by rote strategies. A curriculum based largely on conceptual knowledge runs the risk of being overly 'theoretical'). Furthermore, the curriculum supports knowledge construction, higher order thinking and deep approaches to learning through application, reflection and self-regulation.

Assessment

Assessment, both formative and summative, is directed at all aspects of critical thinking, constructive, cognitive, metacognitive and knowledge. Assessments, group-based or individual, are, typically, authentic, using the typical tools of the community. Assessments evaluate knowledge and 'know how', understanding and competence, content and process.

Community

The environment facilitates individual and collaborative construction as well as participation in social practices, including the sharing of ideas and artefacts with peers (via VLE). Tasks are non-trivial, complex, multi-level and authentic to some community, situated in authentic contexts that require the use of readily available, easy to use authentic tools.

Learner

It is a learner-centred environment in which learners are empowered to learn for themselves and to construct their own knowledge on the basis of prior knowledge and have an opportunity to make and test their own explanations and predictions.

Learners already have (or are able to acquire just in time) sufficient procedural knowledge to operate basic tool features. The environment recognises that learners may have different motivations, dispositions, learning styles, needs, abilities and so on.

Teacher

The teacher's role is largely that of facilitator. The typical instructional strategies are modelling, scaffolding, and coaching. Much of the facilitation may involve facilitating links and productive interactions to other communities.

6.8 Findings vs. Research Questions and Framework

This chapter addressed Research Question 3. The findings in relation to it are summarised below with reference to the critical thinking framework.

Constructive

- No.1: Tools can provide a technical framework which scaffolds construction.
- No.2: Tools can support analysis and synthesis.

Cognitive

- No.3: Tools can facilitate the application of conceptual knowledge in higher order thinking.
- No.4: Tools can facilitate the deepening of understanding.

Metacognitive

- No.5: Tools can expose weaknesses in critical thinking.
- No.6: Tools can make critical thinking more visible.

Knowledge

- No.7: Tools can facilitate the natural acquisition of all the identified knowledge types (factual, conceptual, procedural).
- No.8: Tools can facilitate meaning-making: ‘knowing’ not simply ‘knowing about’

There are some caveats attached to the above list.

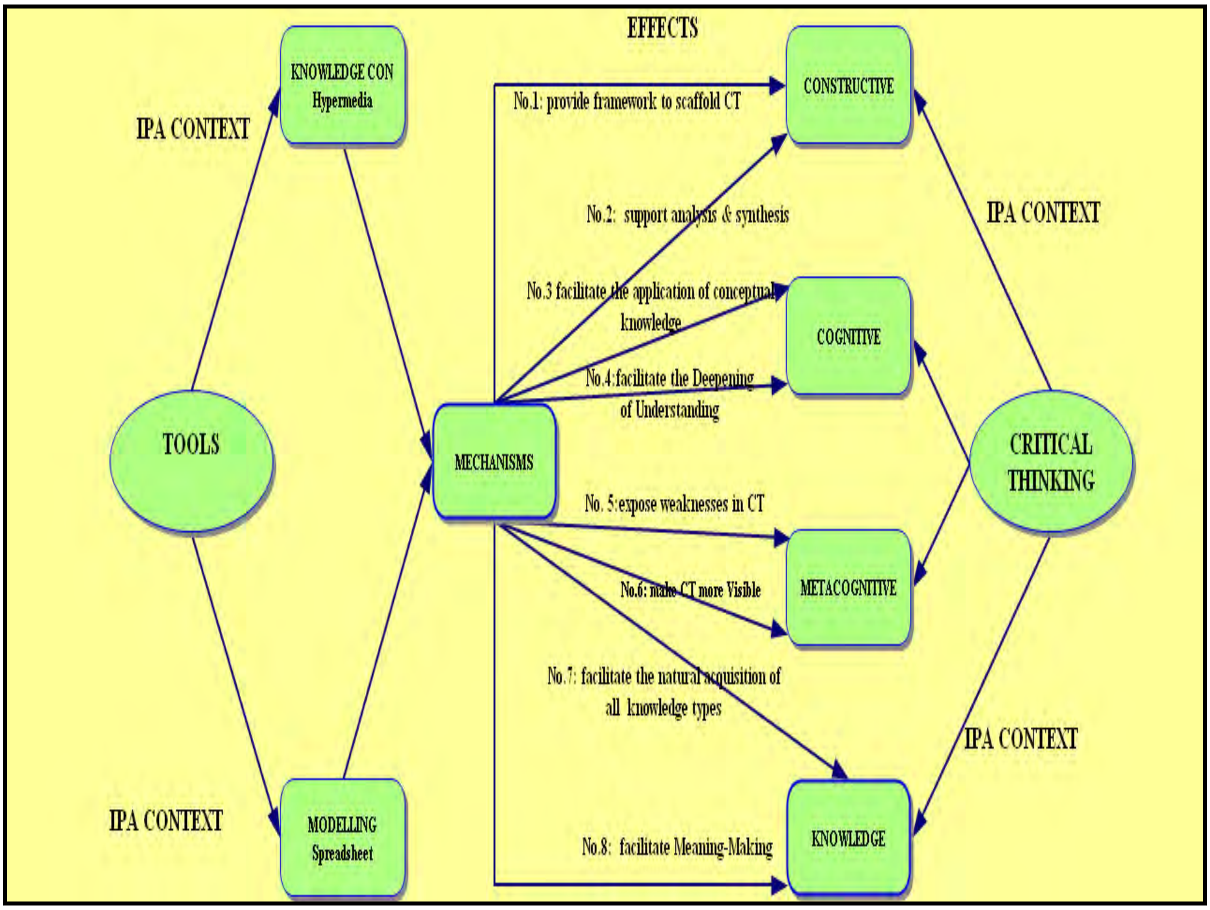
(1) The list is not exhaustive. The effects can be thought of as a small subset of the wide range of effects that tools can enable.

(2) Tools *enable or facilitate* critical thinking effects, but only under certain conditions. When an effect is not produced the tool serves the useful function of pointing to the possibility of some critical thinking defect.

(3) Each effect has been assigned to one aspect of critical thinking. However, since the boundaries between the four aspects cannot be perfectly delineated, nor can the effects.

The diagram below shows how the findings of the study relate to the theoretical framework.

Fig. 6.3: Summary of eight possible critical thinking effects enabled by cognitive tool mechanisms



The table below is an extract from a larger table appearing in Appendix 6.2. This extract, which deals with only one critical thinking effect, namely, '*Tools provide a technical framework which scaffolds construction*', is used for purely indicative purposes to show how the findings relate to the research questions. Column 1 shows the student strengths and weaknesses (i.e., findings in relation to Research Questions 1 and 2). Columns 2 and 3 show a tool-enabled critical thinking effect and its mechanisms (Research Question 3) that are related to the findings in Column 1. Column 4 indicates how the mechanisms might explain the findings and Column 5 offers some examples. The larger table (Appendix 6.2) provides a complete and useful summary of the findings of this chapter.

Table 6.2: Extract from Appendix 6.2 showing one tool-enabled critical thinking effect, mechanisms, related to findings				
Findings: Strengths & Weaknesses	**The tool-enabled effect**	**Technical Mechanisms**	**How do the tool mechanisms explain the Findings?**	**Examples**
Reasonably good at the **synthesising** aspects of the task	**Tools can provide a technical framework which scaffolds construction**:	Overall technical Framework	Tools provide an overall technical framework (consisting of a structural framework and a procedural framework) upon which students can 'hang' their constructs and synthesise components. In order to avail of the technical framework, students must, however, have a conceptual framework to align to it. Thus the technical framework encourages students to develop such conceptual frameworks.	Examples of Predefined structural framework = Database-Table-Field; Book-Sheet-Cell
Strong orientation towards construction		Predefined Core Structure, Templates	The structural framework (e.g., database structure) consists of technical components (database, table, record, field). This structure provides a shell which supports the student constructing. The framework acts as a mechanism that synthesises components of the construct into a coherent whole	The core structure of a database, for instance, provides a framework without which database construction would be very difficult. It points the student to the necessary data components and it provides mechanisms,

				‘relationships’, to enforce the synthesis of the component parts into a coherent database.
Focus on achieving end result Artefacts worked [Teamwork is seen as a key strength]		Predefined Sequences (e.g., Wizards Subtotals Consolidation) Express tools	The procedural framework synthesises construction tasks along a predefined sequence of steps or procedures, thus increasing the probability that the resultant artefact functions correctly. Procedural frameworks encourage users to (1) consider all conceptual frameworks’ components (2) to impose consistent structure or form on the component data and (3) to execute the task in the appropriate sequence. The procedural framework scaffolds the production of ‘professionally’– finished artefacts. Thus, the framework scaffolds the artefacts’ functionality, form and finish.	For instance, the ‘Chart wizard’ is a predefined sequence which scaffolds the construction of graphs. It steps novices through the sequence of actions required to construct a graph (and in the process provides information on conceptual components).

6.9 Chapter Summary

This chapter describes, in some detail, how certain tool-based mechanisms might enable certain critical thinking effects. It discusses eight possible effects covering the constructive, cognitive, metacognitive and knowledge aspects of the theoretical framework. In relation to each of the eight possible critical thinking effects, the account provides examples from the study, a summary of the enabling mechanisms and a description of the enabling conditions. The chapter concludes by showing how this description of mechanisms is related to the strengths and weaknesses identified in the previous chapters – all of which is summarised in a table in Appendix 6.2.

6.10 Reflection

This chapter has been about findings. An important lesson for me has been the gradual discovery that findings, like other aspects of research in the social sciences, are more likely to be conditional than absolute. Much of what we are trying to do in research, it seems to me, is not so much to arrive at the truth but to reduce uncertainty. Research design, the collection of data and the marshalling of evidence can all be viewed as attempts to increase trustworthiness and reduce the uncertainty that surround any findings. Engaging honestly with uncertainty means, ultimately, recognising that our explanations of uncertainty (i.e., our findings) are often limited, conditional and coloured by our individual perspectives.

I am now more of the view that 'how things look' and what they mean depends at least as much on the perspective of the observer as on 'the things' themselves. For instance, I see parallels, on reflection, between my own learning and the learning of the students that I observe. For example, their difficulties in applying theory to practice, their blindness, sometimes, to their faults and failings – and how constructing can make these visible – the challenge of adopting deep approaches to learning (below), their joy with the end result, their quest for meaning – all of these findings, on reflection I discover, are mirrored in myself. Then the obvious question is: Is what I have observed in my students really part of them or just a reflection of myself?

The perspective that I brought to the research included much useful prior knowledge and experience – from the ancient classics, statistics and information systems, from learning theory and 30 years' experience of teaching. Against that prior knowledge, I have tried to assimilate and test my newfound ideas about tools and critical thinking in such a way as to make meaning for myself. I am happy that my intention has always been to 'get to the bottom of things' – an impossible goal but it does facilitate deep approaches to learning.

Taking into account the misgivings outlined above, I feel that the findings I have produced offer a reasonably coherent and original account, at a fine level of detail, of the mechanisms by which tools can enable critical thinking effects and how these help to explain or expose students' strengths and weaknesses in critical thinking.

CHAPTER 7: IMPLICATIONS FOR PRACTITIONERS (RESEARCH QUESTION 4)

7.1 Introduction and Purpose

The previous chapters addressed Research Questions 1 to 3. This chapter addresses Research Question 4: the implications of the study's findings for teaching in the IPA. The purpose of this chapter is to demonstrate, in a way consistent with the theoretical framework, how the findings can be translated into a set of accessible teaching guidelines for use by IPA teaching staff. This is a two-step procedure: firstly, broad instructional precepts are derived from the findings and secondly, the broad precepts themselves are transformed, by means of a pattern language, into detailed guidelines.

In this chapter we introduce the concept of pattern language, where a pattern can be thought of as an entity that provides essential advice on a recurring problem in a given domain. The chapter concludes by providing samples of how patterns might be used to produce a set of detailed, practical guidelines for IPA teachers – an important objective of this research as indicated at the outset of this study.

7.2 Research Review: Research Questions, Theoretical Framework and Methodology

This chapter addresses Research Question 4.

Table 7.1: Research Question 4
4. Implications for teaching What are the implications for teaching and learning in the IPA context? How might the findings be translated into set of practical guidelines or 'rules of thumb' which IPA tutors can use?

The research question is dealt with in the context of the theoretical framework for critical thinking, used throughout the study, which characterises critical thinking as constructive, cognitive, metacognitive and knowledge-based.

7.3 Broad Precepts

The previous chapter set out eight possible critical thinking effects (Appendix 6.2), which tools could facilitate. The table below, based on (Appendix 6.2), shows data relating to just *one* tool-enabled critical thinking effect, namely, *Tools provide a technical framework which scaffolds construction.* To it has been added, in the rightmost column, broad instructional precepts. Each precept should be considered as just *one* way to facilitate, from an instructional perspective, that tool-enabled, critical thinking effect. For instance, the precept '*Devise authentic, construction tasks'* is just one way of facilitating the above mentioned critical thinking effect *Tools provide a technical framework which scaffolds construction*: Appendix 7.1 contains a summary of all tool-enabled critical thinking effects and broad instructional precepts designed to support those effects.

The precepts are based on the following assumptions about instructional design (ID):

ID is made up of a number of activities. However, these activities and their sequence are not universally agreed. Nonetheless, there is broad agreement that ID includes

‘Devising Objectives/Outcomes’, ‘Developing/Deploying an Instructional Strategy’ and ‘Assessing’ (Gagne et al., 1992; Reigeluth, 1999).

‘Instructional Strategy’ may take many forms depending on the situation. Important activities in constructivist approaches to Instructional Strategy are modelling, scaffolding, coaching and fading (Jonassen, 1999; Stone and Goodyear, 1995; Biggs, 1999).

Since one cannot prescribe for every minute detail, the advice offered here is situational and non-directive (Reigeluth, 1999).

The learning environment is learner-centered and focused on higher order learning and critical thinking outcomes, and learners are encouraged to explore the field of knowledge for themselves.

The teacher’s role is more of a facilitator and coach (‘guide on the side’) than instructor or the repository of all knowledge (‘sage on the stage’). What this means for my own teaching is discussed in the Chapter 1 ‘Reflection’ and the Chapter 8 ‘Reflection’.

All design is about trade offs: to encourage students to use technologies with which the teacher may be less familiar than the students may mean trading teacher control for student empowerment. The decision will be situation-dependent.

Table 7.2: An example of one tool-enabled critical thinking effect with corresponding broad instructional precepts

The tool-enabled effect	Technical Mechanisms	How do the tool mechanisms explain the Findings (e.g., support a strength or expose the weakness)?	Broad Instructional Precept
Tools can provide a technical framework which scaffolds construction:	Overall technical Framework	Tools provide an overall technical framework (consisting of a structural framework and a procedural framework) upon which students can 'hang' their constructs. In order to avail of the technical framework, students must, however, have a conceptual framework to align to it. Thus the technical framework encourages students to develop such conceptual frameworks.	1. Devise authentic, construction tasks using authentic tools which encourage students to avail of the tool's technical framework. 2. Model appropriate tool use, especially the 'knack' of exploiting the technical framework and similar 'tricks of the trade'.
	The Core Tool Structure Templates	The structural framework (e.g., database structure) consists of technical components (database, table, record, field). This structure provides a shell for the student constructing. The framework acts as a mechanism that synthesises components of the construct into a coherent whole.	3. Provide ongoing coaching on all aspects of construction

	Predefined Sequences (e.g., Wizards Subtotals Consolidation) Express tools	The procedural framework synthesises construction tasks along a predefined sequence of steps or procedures, thus increasing the probability that the resultant artefact functions correctly. Procedural frameworks encourage users to (1) consider all conceptual frameworks' components (2) to impose consistent structure or form on the component data and (3) to execute the task in the appropriate sequence. The procedural framework scaffolds the production of 'professionally'-finished artefacts. Thus, the framework scaffolds the artefacts functionality, form and finish.	4. Scaffold student construction by the use of procedural frameworks 5. Align assessment criteria for authentic tasks to the authentic criteria of the community of practice, relating such criteria to form, functionality and finish.

Broad instructional precepts for the remaining tool-enabled, critical thinking effects have been summarised in Appendix 7.1.

7.4 Transformation of Broad Precepts into Practical Guidelines: A Pattern Language

The broad instructional precepts, helpful in themselves, need to be detailed and made more explicit if they are to be of greater use to the practitioner. This study uses ‘pattern language’, the subject of this section, to transform these precepts into more concrete practical guidelines.

A pattern language consists of entities called patterns. Each pattern is composed of elements. Each pattern deals with a recurring problem or issue in a domain and provides a core solution or advice.

Professor Christopher Alexander created such a pattern language for his seminal work on town planning and architecture (Alexander et al., 1977). His language sets out to provide *guidance* for the layman on the design and construction of the urban environment. In it he provides non-directive advice – patterns – on issues affecting the design of all aspects of a house. Examples of his 253 patterns are ‘bathing room’ (144), ‘six-foot balcony’ (167) ‘outdoor room’ (165) and ‘alcoves’ (179). Taking a different example, a pattern language for web design might include the following patterns: java programming, aesthetics, page layout, graphical elements, hyperlinking, colour scheme, security. In each of the above cases the pattern provides non-directive guidance on the issues determining the design and construction of the entity to which it refers. Two examples of Alexander’s patterns – ‘garden seat’ (176) and ‘bed alcove’ (188) – appear in Appendix 7.2.

The elements of the pattern typically include Heading, Description of the Problem, Graphical Image, General Description of Core Solution, and References to other patterns. In Alexander's work each pattern consisted of one or more printed pages so that the pattern language took the form of a book. In this study the intention is to provide text-based patterns which will, ultimately, become the basis, not for a book, but for an electronic, web-enabled pattern language.

The patterns are both standalone and interrelated. This interrelatedness is 'fundamental': 'when you build a thing' as Alexander puts it, 'you cannot merely build that thing in isolation' (Alexander et al., 1977: xiii). When all the patterns are assembled into a pattern language, the purpose is to provide a coherent picture of an entire region or domain and guidance on how to generate such regions or domains in a multiplicity of ways. In this way, you can, as Alexander asserts, use the pattern language, for example, to design a house for yourself.

The pattern language is non-prescriptive. It provides core solutions in sufficiently general terms as to allow them to be translated into 'a million forms' (Alexander et al., 1977: xxxv).

A pattern language is evolving. Others can make their own patterns or contribute to a public pattern language. For example, in Alexander's language there is no pattern for a sauna. One might add a pattern for this relating it closely to the pattern for 'bathing room' (144).

> 'It is possible that each person may... embark on the construction and development of his own language, perhaps taking the language printed in this book as his point of departure' (Alexander et al., 1977: xvii).

This is the challenge that is now taken up here: the development of a pattern language to translate the findings into set of practical guidelines on tool-enabled critical thinking which IPA tutors can use (Research Question 4).

7.4.1 Justification for the use of Pattern Language as a Bridging Tool

Background

Research Question 4 is directed at how 'the findings can be translated into a set of practical guidelines or 'rules of thumb' which IPA tutors can use'. Reasons as to why pattern language is an appropriate vehicle for this translation are set out below.

Multiplicity

The discourse on critical thinking is characterised by a multiplicity of views. Pattern language was designed to accommodate such multiplicity. It is not, as noted above, a manual – *mode d'emploi* – that provides the *one* right answer to a well-defined task in a sequenced set of steps.

Non-prescriptive

The discourse on critical thinking is characterised by uncertainty. The non-prescriptivity of the pattern language suits such uncertainty.

Links

In the field of critical thinking boundaries, such as those between its constructive, cognitive, metacognitive, and knowledge aspects cannot be clearly drawn. Pattern language is deliberately designed so that one pattern overlaps with others by means of links.

Cognitive Tool

'Cognitive Tools' and 'Critical Thinking' are focal points of this research. The pattern language is a representation of this, in miniature. It is, itself, a cognitive tool designed to support the incorporation of critical thinking into IPA accredited programmes.

7.4.2 The Pattern Language and the Theoretical Framework

Immediately below we show how the pattern language is related to the key aspects of the theoretical framework for critical thinking: constructive, cognitive and metacognitive skills and knowledge.

Critical thinking is constructive. The view of critical thinking in this study, as noted in Chapter 2, focuses more on the construction of artefacts than of arguments. Thus, it is natural that findings about critical thinking emerging from this research will be, ultimately, transformed into an artefact – in this case an electronic web-enabled pattern language. Furthermore, since knowledge is not just constructed in the head of the knower, but is also co-constructed by groups and communities, it is envisaged that the next version of the language will be available as a public pattern language to be updated by all members of the IPA teaching community.

The pattern language is a cognitive tool. By definition, it supports the development of the cognitive aspect of critical thinking.

As regards the metacognitive aspect of critical thinking, the pattern language is designed as much to encourage reflection as it is to inform. In most patterns there are reflective elements.

As regards the knowledge aspect of critical thinking, in the exploration of any issue, each pattern explicitly discusses both conceptual knowledge and procedural knowledge (in the form of 'rules of thumb' or directive advice).

Discussing the importance of translating research into practice, the Design-Based Research Collective also talk in terms of the usefulness of patterns:

> 'In design-oriented fields, design knowledge is often characterized by common examples, **patterns**, and principles, and by the expertise required to apply these generalities in specific settings…. [such] research communicates this knowledge….[in] narratives, …. design principles …. and design **patterns** …. describing how a designed innovation interacts with settings and evolves' (DBRC, 2003: 8) [bold added].

7.4.3 Sample Patterns

A sample pattern appears below. The pattern is designed to elaborate the broad instructional precept above – '*Devise authentic, construction tasks,* etc.' (Precept No. 1 above).

The reader should bear the following in mind when looking at the pattern:

The pattern has a number of elements: Their names appear in the first column. They include Heading, Key issue, Common Error and so on. (The first two elements 'critical thinking effect' and 'broad precept' are for reference purposes only).

The pattern is represented below, *for convenience only*, as a table. In its final form the pattern will be web-enabled. This has certain important implications.
Currently the pattern is read from top to bottom in a linear fashion. When the pattern is web-enabled each element will be standalone (a 'chunk' of text), readable in any order (non-linear).

The standalone chunks will be related via hyperlinks, marked as underlines.

Much information, which cannot be conveyed directly in this paper tabular representation, will be made available indirectly in the web-enabled form to the reader via hyperlinks. Readers can follow a link to acquire more information if they so wish.

The language, tone, content and conventions are deliberately more informal than what is normally found in academic discourse. For instance, references are not explicitly provided to support claims. Nor is it claimed that every aspect of each pattern has direct empirical support from this thesis. However, the patterns do reflect mainstream trends in the literature on learning and instructional design. Often a pattern provides detail on a pre-existing idea such as scaffolding but discusses it in the context of tool use.

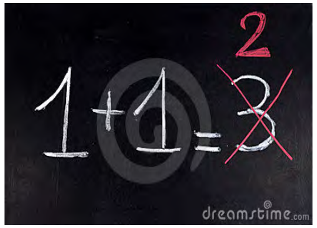
The examples are directed at the IPA teaching context and may not always make full sense to the outside reader but can be easily generalised to other contexts.

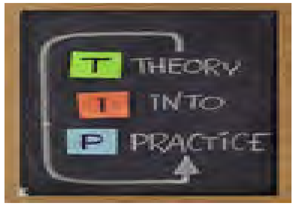
The pattern language is best used in conjunction with the training programme that is envisaged for IPA staff.

The pattern language, as noted earlier, is evolving. Others can make their own patterns or contribute to a public pattern language.

The pattern below relates to the constructive aspect of critical thinking. Three further sample patterns appear in text form in Appendix 7.3. Each pattern is based on a broad instructional precept for the tool-enabled, critical thinking effects summarised in Appendix 7.1. These patterns have been selected in order to cover all remaining aspects of the critical thinking framework – cognitive, metacognitive and knowledge. The purpose of each sample pattern is to convert *one* broad precept into a detailed set of practical guidelines (the intention is to provide, over a much longer period of time, a full pattern language for this domain, which will be web-enabled. For the current research purpose only a small, representative subset of patterns has been provided).

Critical Thinking Effect	Constructive: Tools can provide a technical framework which scaffolds construction
Broad Precept	Devise authentic, construction tasks that require authentic tools.
Heading	**Devise authentic tasks**
Key Issues 	'It's all fine in theory but….' – No doubt, you have heard this from students before, maybe many times. Take a moment to reflect on what they might mean when they say this? Maybe they were referring to the fact that what they were learning was, in their view at least, too text-bookish or impractical or would not work in real life. Devising a strategy, for example, is a real-life, authentic, critical thinking task for a county manager; examining a patient is an authentic task for a doctor, just as making a presentation is an authentic task for a teacher or trainer. An authentic task is a real-life task or a task which is similar, in certain critical respects, to the real-life task. When pilots train on a simulator the task is not, strictly speaking, real. It is, however, authentic since it is sufficiently similar to the real-life task as to be meaningful. Examples of authentic tasks in the classroom are: • a role play of a selection interview in a human relations program, • the design of a website in a course on information systems, • the preparation of a balance sheet on a finance course • devising a contingency plan on a management development program. Authenticity is important because: • The closer the task is to the real-life task the easier it is to <u>transfer</u> what has been learnt in the classroom to the target environment (e.g., workplace). This explains why someone arriving in Paris with 'book-French' has difficulties with the authentic language that is spoken on the street. Indeed maybe you have had a similar experience. • It is generally easier for students to see the relevance of authentic tasks. This is <u>motivating</u>.

Common Error  	Authentic tasks are the 'opposite' of text-book problems – contrived problems with often contrived solutions, clear-cut right and wrong answers. Text-book problems sometimes dominate a learning program. This is best avoided.
General Advice  	The best kinds of authentic tasks to choose are design and make tasks. Examples of design and make tasks which promote critical thinking are: • creating a survey, • inventing a new product, • creating a database, • devising an advertisement, • creating a (learning) portfolio. In the completion of any authentic task, you might like to orient students' critical thinking to three elements – functionality, form and finish. In the case of a video, for instance, ask yourself does it do the job it was intended for – does it get the message across (functionality)? Is it well structured (form)? Does it have a professional look and feel (finish)? These three fundamental questions apply to any authentic task. Look for authentic tasks that promote critical thinking and higher order learning skills such as analysing, applying, evaluating and creating. In the context of critical thinking you will want to avoid tasks that are low-level and repetitive.

<table>
<tr><td></td><td>Try to integrate the authentic tasks into the overall design of the learning program. For instance, an authentic task such as ‘devise a training plan for your organisation and make an online presentation of it’ could be used to introduce a framework for training or could be used to reflect on such issues.</td></tr>
<tr><td>Tips/ Rules of Thumb

</td><td>
Get students to identify authentic tasks that interest them. Assigning tasks that don’t interest students is counterproductive.
Keep exercise instructions short (less than a page). Let students use their own authentic experiences to fill in the blanks. Click on Examples.
Invest a lot effort in coaching, especially in the early phases of the task.
</td></tr>
<tr><td>Tools
</td><td>Here are some useful tools (These critical thinking tool-based tasks can, with a little customisation, be made authentic to a wide range of situations).
<table>
<tr><th>Tool</th><th>Task</th></tr>
<tr><td>Survey monkey</td><td>Do a little original research using this survey tool</td></tr>
<tr><td>Basecamp</td><td>Plan and manage a project of any kind</td></tr>
<tr><td>MS Word (simple web design)</td><td>Design a simple website
Create a web-enabled portfolio</td></tr>
<tr><td>Spreadsheet</td><td>Create a cost benefit analysis or any numerical analysis e.g. what-if analysis, etc., etc.</td></tr>
<tr><td>Slideshare, PowerPoint</td><td>Showcase project work</td></tr>
<tr><td>YouTube</td><td>Design, make and upload a short video about any aspect of your courses</td></tr>
<tr><td>Facebook, Twitter</td><td>Students collaborate online outside class, say for project work</td></tr>
<tr><td>PhotGallery, Flickr</td><td>Students design and make multimedia presentations</td></tr>
</table></td></tr>
</table>

7.5 Findings/Outputs vs. Research Questions and Framework

This chapter addressed Research Question 4. The findings/outputs in relation to it are summarised in the table below with reference to the critical thinking framework.

Table 7.3: Research Questions 4 and Findings/Outputs

Research Question 4	**Tool-enabled, Critical Thinking Effects and Framework**	**Output Broad precepts**	**Output Patterns**
Implications for teaching What are the implications for teaching and learning in the IPA context? How might the findings be translated into a set of practical guidelines or 'rules of thumb' which IPA tutors can use?	Eight Tool-enabled, Critical Thinking Effects across the key aspects of the theoretical framework Constructive Cognitive Metacognitive Knowledge	The implications of the findings (Eight Tool-enabled, Critical Thinking Effects) for teaching and learning in the IPA context are laid out as sets of broad precepts for the constructive, cognitive, metacognitive and knowledge aspects of the theoretical framework.	Some broad precepts have been translated into a sample set of practical, detailed guidelines (patterns) which IPA tutors can use The patterns ultimately will form a language which will provide detailed, non-directive advice on issues affecting the design of teaching and learning the four key aspects of tool-based critical thinking.

By way of conclusion to this chapter, it is worth remembering the following points:

The patterns are not presented as the ‘right answer’ or as a definitive course of action. The patterns are intended to suggest possible paths forward. Others will have the opportunity to test these empirically as part of the training program.

The question might arise as to how far research of this scale should be used to redefine IPA policy and practice. It is hoped that the research here will influence policy but it is recognised that it is not the sole determinant of it. Other factors such as the views of senior management and colleagues all have an important bearing on policy and practice in this area. Indeed, without some agreement by stakeholders it would not be possible to progress research to implementation. Dissemination of findings and implementation of research are discussed more fully in the final chapter.

Pattern language itself has limitations. As a form of ID it is not independent, it requires the designer to have some coherent understanding of both learning theory and more broad-based ID, such as that of Gagne. Furthermore, successful use requires combination with traditional human intervention: guidance and coaching.

Since Alexander published his work, a good deal has been written on pattern language and ID. Constraints on space prevented any serious attempt to provide a critical review of this work. This could be profitably rectified in future work.

It might also be objected that the broad approach taken to instructional design in chapter 7 is in contrast with the narrow focus and detailed findings of chapter 6. It is acknowledged that this, indeed, is an awkward transition. However, some such device is required to bridge the gap between the research complexity and routine practice that will provide IPA tutors with ideas that can be applied to higher order learning and critical thinking. The critical review of literature on ID, referred to in the paragraph above, should help smooth out the transition.

7.6 Chapter Summary

This chapter first translates the findings of Chapter 6 into *broad* pedagogic precepts. It then shows how pattern language can be used to convert the broad precepts into a detailed set of non-prescriptive guidelines for IPA teachers. In so doing, it describes the nature and structure of pattern language, which consists of interrelated patterns, and which provides a coherent picture of an entire domain, such as critical thinking, and offers non-prescriptive guidance that allows recurring ‘problems’ to be solved in a multiplicity of ways. Its non-prescriptivity, interrelatedness and fluidity, make it an ideal tool for translating broad precepts into more detailed practical advice and ‘rules of thumb’. The chapter concludes by summarising the relationship between Research Question 4, the theoretical framework and the pattern language and by alluding to some of the limitations of pattern language. Sample patterns have been provided.

7.7 Reflection

Since this chapter has been concerned with patterns one might reflect that the structure of this thesis also follows *roughly* a well known pattern: Introduction, literature review, data collection and analysis, discussion and conclusions. Furthermore, many individual chapters follow a similar the pattern: Introduction, review, findings, summary and reflection. Symmetry such as this, within and between chapters, is characteristic of many pattern types.

The job of the researcher, at least of this researcher, is not only to collect and describe data but to look for the pattern underlying the data he collects, through the analysis process to make sense of data. The use of statistics, in our case, exploratory data analysis, is one way of detecting such patterns. Content and textual analysis are other techniques in the thesis used to arrive at meaning by exploring patterns underlying surface discourse. Needless to say the pattern detected and the meanings arrived at, from one and the same corpus of data, can vary widely depending the researcher – which brings us back, once again, to the subjectivity of the research.

Patterns are ubiquitous. Examples include the zigzags on a rug, the hexameter verses in Virgil, Shakespeare's three stanza, 14 line sonnet structure, the normal curve or the Fibonacci sequence in mathematics or clusters of population on a map in geography. To this list of patterns, in any field, such as the learning sciences, we may add the notion of best practice as pattern and a pattern language to capture it.

In the case of tailoring, the paper pattern is on the cutting table but the quality of the suit will depend greatly on the tailor's interpretation of best practice, the accuracy of the cut, the fineness of the stitching. This is what separates master-tailor from novice. The novice only becomes master through apprenticeship that points to shortcomings, coaches on solutions, and encourages best practice. As for the patterns in this thesis, the

IPA tutor designers, also, must be given some help in interpreting the pattern and bringing their own skills to bear upon it.

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CHAPTER 8: THESIS SUMMARY, DISSEMINATION AND FURTHER RESEARCH

8.1 Introduction and Purpose

This chapter provides an overview of some key ideas and findings in the study. Its purpose is not to provide a detailed summary of the research but rather to reflect on some of the study's emergent themes and show how these relate to some of the more important theoretical ideas discussed in Chapter 2. Similarly, it revisits and reflects on the shortcomings of the theoretical framework. Finally, it points to a number of promising topics for future research.

8.2 Research Review: Research Questions and Findings

The study set out to address a number of research questions which appear at the end of Chapter 2. The main findings of the study, summarised at Appendices 6.1 and 6.2, indicate that students are reasonably strong on the constructive and knowledge aspects of critical thinking – especially in relation to goal achievement and synthesis – but somewhat weak on the cognitive and metacognitive aspects, displaying sometimes a lack of depth, inadequate analysis and planning and an underdeveloped metacognitive awareness.

In relation to the above, the study suggested that tools, under appropriate conditions, may enable certain critical thinking effects, such as those summarised below:

- Tools can provide a technical framework which scaffolds construction.
- Tools can support analysis and synthesis.
- Tools can facilitate the deepening of understanding.
- Tools can facilitate the application of conceptual knowledge and higher order thinking.
- Tools can expose weaknesses in critical thinking.
- Tools can make critical thinking more visible.
- Tools can facilitate the natural acquisition of all knowledge types (factual, conceptual, procedural).
- Tools can facilitate meaning-making.

To facilitate each of these tool-enabled critical thinking effects the study first proposed a number of broad instructional precepts. Secondly, these broad precepts were, in turn, detailed, by means of a pattern language, into more concrete practical guidelines or 'rules of thumb' on tool-enabled critical thinking which IPA tutors can use – the ultimate objective of the study.

8.3 Themes and Theory

A number of themes, which underpin the above findings, recur in the study and thus invite us to reflect on some of the theoretical positions outlined in Chapter 2.

One recurrent theme in the study is that critical thinking makes special use of the interplay of procedural and conceptual knowledge (Anderson et al., 2001). For instance, one might reasonably suggest that procedural knowledge, necessary for any tool-enabled construction, also invites students to revisit their conceptual knowledge. Thus, when designing an EIS the student is obliged to confront questions that are not just procedural but also conceptual. I have argued that the mastery of procedural knowledge is not the major challenge of instructional tool-based constructive learning, but rather the ability to transform conceptual knowledge into a working artefact by means of procedural knowledge – a key process by which the student comes to understand what the conceptual *means* in practice. The interplay of procedural and conceptual knowledge reminds us of Ennis's (1991) definition of critical thinking, quoted in Chapter 2, as knowing 'what to believe or what to do'. But, is Ennis implying that belief precedes action? In Chapter 6 we suggest that the meaning of the conceptual may often emerge out of the procedural, the abstract out of the concrete. If this is right, it ties in well with Dewey's view (Chapter 2) that students '*first*…. have a genuine situation of experience' [italics mine] and through the process of application of ideas, ultimately make meaning out of their experience.

In Chapter 2 we refer to the view of Jonassen and Carr (2000) that tools 'enable learners to represent what they know'. 'Representation' remains an important idea in any discussion of tools and this research offers one tentative explanation of how this idea might be worked out with reference to artefactual representation (Nardi, 2001). I have argued in Chapter 6 that 'the alignment of the conceptual to the technical' requires students (1) to be *conscious* and *explicit* about the alignment (2) to be clear on the *meaning* of each of the conceptual components (3) to consider *the hierarchy of levels* in which the conceptual components are ordered and how these are to be aligned to the technical *hierarchy of levels in the tool* (4) to consider how conceptual links between components are aligned to the technical hyperlinks of the tool components.

The recent emphasis on the self-regulatory (Facione, 1990: 2), reflective (Ennis, 1992) or metacognitive (Paul et al., 1993, Pintrich, 2002) aspect of critical thinking, discussed in Chapter 2, seems to me an important one. In Chapter 6 we pick up on this theme and go on to suggest parallels between the cognitive and metacognitive aspects. For example, in relation to the cognitive aspect of critical thinking, evidence from the study indicates that just as students' understanding can be often shallow, so too students' *understanding of their understanding* is also often shallow.

Authenticity is also a recurrent theme. Critical thinkers work on authentic tasks, using authentic tools. Thus the teaching and learning of critical thinking is likely to be best accomplished by exposure to authentic tasks, using authentic tools. 'Design and make' tasks are typical of many critical thinking tasks and are particularly useful in instructional settings since they require both analysis and synthesis. Dewey (Chapter 2) emphasises the authentic – he uses the word 'genuine' – when he speaks of pupils having 'a genuine situation of experience' and that they should be required to address 'genuine problems' within real-life situations (1944: 163). Authenticity, however, mostly resonates of Wenger's (1998) communities of practice and other sociocultural accounts of learning (Hill and Plath, 1998). In that context, the study, designed using authentic tasks and authentic tools, may be seen as a way of facilitating change and as a tool to bridge the gap between research and what Saunders called 'embedded practice' (Saunders et al., 2005: 43).

8.4 The Critical Thinking Framework Revisited

There are a number of issues in the framework for critical thinking on which I have shifted my initial thinking somewhat.

My perception of the framework has changed from reasonably well defined to more uncertain. By that I mean we do not know exactly how to define the framework's components or their boundaries. For example, the knowledge component and the metacognitive component are treated here as separate components, whereas, according to Anderson et al. (2001), metacognition is, simply, a subcategory of the knowledge component. Likewise we do not know how the components are interrelated; nor do we know the relative weighting or importance of each component in the model. We cannot say, for example, if the knowledge component is more important (that is, 'carries more weight') than the cognitive component.

My understanding of the mechanisms by which tools may enable critical thinking effects (Appendix 6.2) has changed from a general to a more detailed one. The model now provides detail on some critical thinking effects that tools might enable and some detailed suggestions about the mechanisms that might be at play in enabling them. We return to this in the next section.

Other shifts in my thinking include a greater appreciation of the metacognitive aspects of critical thinking as well as a move from a largely cognitive conception of it to a greater recognition of its social and affective aspects. While the social aspects of critical thinking were not explicitly included in the research, the study not infrequently points to their importance. We return, briefly, to the metacognitive and affective aspects of critical thinking in the 'Reflection' below.

8.5 Originality and Contribution of the Thesis

As regards originality, much of the earlier work on critical thinking and on cognitive tools has been at a rather general level. The most original aspect of this thesis is that it has tried to develop a provisional set of ideas, at the micro level, of how tools might enable critical thinking effects and what the enabling tool mechanisms might be. For example, for each tool-enabled critical thinking effect, we point to the individual tool mechanisms that may enable it (template, wizard, subtotal, consolidation), offer an explanation of how that mechanism may enable the critical thinking effect and finally we give examples of this. All this is summarised in Appendix 6.2.

The above applies to each tool-enabled critical thinking effect. Focusing on just one specific example gives an insight into how this account has built on, but is also different from, earlier work. For instance, in Chapter 2 it was noted that earlier research suggested that tools might scaffold critical thinking. In Chapter 6 of this account, we detail this idea and show how tools might accomplish this. We suggest, for instance, how tools have an overarching predefined technical framework, divisible into structural and procedural frameworks. In the case of the former, we 'theorise' that students lean on these core predefined structural frameworks to construct their models. However, in order to avail of the structural framework, students must have a conceptual framework to align to it. This, in turn, requires students to be reasonably clear on the *meaning* of each of the conceptual framework's components and how they relate to one another.

Aside from the development of a provisional set of ideas relating to tool-enabled critical thinking effects, this account also offers a somewhat different definition of critical thinking than heretofore. For instance, in Chapter 2 it foregrounds the constructive rather than the analytical, it emphasises construction of artefacts rather than arguments, it focuses on the metacognitive as much as the cognitive and it moves away from conceptions of critical thinking that honour general knowledge and reasoning over more domain-specific knowledge. In Chapter 6 evidence is produced to corroborate these views.

8.6 Dissemination of Findings

At the outset of the thesis we discussed issues relating to the IPA's immediate environment and its wider environment. I outline the steps here that I propose to take to disseminate the findings of this study with regard to both of these.

- Provide the Director General of the IPA with a full briefing on the study and seek his approval for the steps below.

- Organise a meeting with the fellow section heads and directors of the accredited programmes to discuss the findings and their implications for each of the accredited programmes. Organise a workshop for the teaching staff of the accredited programmes to explain findings and discuss their implications with them. What is envisaged here is the facilitation of a democratic or consensual approach to change where change is not imposed from the top-down but where the teachers are themselves encouraged to be agents of change (Fullan 1993).

- Upload fully web-enabled Patterns to the IPA intranet, organise an online discussion to get feedback.

- Review and Planning of next steps to implement a detailed training program.

As regards the wider environment,

- Discuss with the directors and the teaching staff of the accredited programmes the relevance of the findings to specific target groups in the immediate and wider IPA environments: managers, policy makers and professionals.

Saunders (2005:42-43) has characterised the evolution of change in terms of 'enclave'- 'bridgehead'- 'embedded practice'. This research, also, can be conceived of as a bridgehead or a platform for change. In the evolutionary process of this research it is envisaged that the change will move from individual researcher to IPA teacher community and toward embedded practice through reifications such as the web-enabled patterns, discussion forums, and training courses as well as other emergent structures. Thus this research, as noted above, might be reasonably seen as a bridging tool by 'providing bridging resources for participants' (Saunders, 2005:42).

8.7 Further Research

8.7.1 Patterns, Examples and Best Practice

> 'Design knowledge is often characterized by common examples, patterns, and principles, and by the expertise required to apply these generalities in specific settings' (DBRC, 2003: 8).

As a next step, the pattern language could be expanded to allow teachers to contribute 'common examples' and 'principles' of their own good practice. These contributions might take the form of new patterns or would supplement already existing patterns. All of this might be encompassed within a participatory action research design. The benefits of this might include

- the ownership of ideas and improved implementation of best practice;
- the dissemination of findings among a larger audience;
- the building of links between research and practice; and
- enlarging the repository of usable resources.

8.7.2 Context

The research currently focuses on the domain of Information Systems set in the classrooms of a university college. Research which extended the study to other domains, students and settings, such as online collaborative learning in the humanities domain, would provide the basis for more generalisable claims.

8.7.3 Collaborative Approaches and Social Networking Tools

Critical thinking may also be enabled by non-technical mechanisms such as collaborative learning. At a time when the advent of Web 2.0 tools is much talked about, it seems appropriate that that research should focus on the mechanisms by which such social networking tools can enable critical thinking effects. Such research might seek to determine

- different categories of social networking tools;
- their constructive, cognitive, metacognitive and knowledge-based effects; and
- the interaction between social practice and technical practice.

8.7.4 Critical vs. Creative Thinking

Much valuable knowledge could be accumulated by conducting a study into the relationship between cognitive tools and *creative* thinking. The aim of such a study would be to determine the mechanisms by which cognitive tools may promote creative thinking, to determine if these are significantly different from those that enable critical thinking, and, ultimately, to determine what such a study might tell us about supposed differences between critical and creative thinking.

8.7.5 Methodology

The research is not without its limitations:

The OLD instrument, for instance, does not allow any probing of the contributor's opinions or feelings. It could have been profitably supplemented by interviews.

The COGITASK could be better defined: more emphasis could be placed on the contribution of experts (e.g. web designers) to its design and to how it should be assessed. This could also be more clearly mapped to Bloom's taxonomy to ensure the resultant MS is as unambiguous as possible.

The COGITASK data might have been usefully triangulated against standardized CT inventories and also IPA exams.

A small sample of the tutors and directors could have been interviewed in depth. This could have helped to identify research issues and also to develop a platform for post-study implementation. This would also have enabled tutors' and students views' to be triangulated.

One might argue about causality in the study. For instance, consider the research question: 'By what mechanisms, and under what conditions might tool use enable/facilitate critical thinking?' The assumption is that it is tool use that facilitates critical thinking, whereas the reverse is just as possible: effective critical thinkers are likely to be more adept at *cognitive* tool-use than people who are not effective critical thinkers. If this is the case how do we set about disentangling these effects? It is not possible to conclude with certainty on this point within the limitations of this study.

> 'We suggest that the value of design-based research should be measured by its ability to improve educational practice' (DBRC, 2003: 8).

Further Research, the methodology of which supports the above objective and which may clarify the above issues, is likely to be characterised by:

- The assumption that there is no *one* right answer. What works in one context may not work in another. Therefore rich, context-situated accounts of the practice of critical thinking teaching and learning are to be encouraged.
- Research needs to be designed not only as a more synergistic enterprise between researcher and practitioner but also to support the researcher-practitioner roles. For instance, while I refer from time to time, often through the end-of-chapter reflection, to my own role in the study, I do not explicitly evaluate that role in

the research. Further research might provide more developed methodologies for doing this and offer useful insights into the interactive impacts of teacher and researcher roles.

8.8 Summary

The chapter has presented an overview of the findings and key themes of the study, a critique of the framework and some pointers to further research. The study, more generally, set out to address four research questions concerning the relationship between cognitive tool use and critical thinking. It has specified a number of critical thinking effects and attempted to demonstrate, at a fine level of detail, how tool-based mechanisms can enable these and under what conditions. It has then translated these findings, by means of pattern language, into an accessible set of guidelines for IPA teachers.

8.9 Reflection

Since the last two chapters have dealt with the research implications for teaching, I reflect now on how certain aspects of my role(s) as teacher, facilitator and coach have changed as a result of my research. This reflection picks up a number of themes that arose in the Chapter 1 'Reflection'.

I now pay more attention to the explicit teaching of the metacognitive aspects of critical thinking. I explain what metacognition means and ask students to reflect on it. I also model metacognitive processes. For example, when an unexpected exception to a routine method occurs, I talk the students through (out loud) *what I am actually* *thinking,* why I am handling this step the way that I am and what, I think, 'my next move' will be. I do all this – to paraphrase Richard Paul (Chapter 2) – *while I am thinking in order to make my thinking better: more clear, more accurate* (Paul, 1992: 11).

Metacognition involves being aware both of our thoughts, e.g., 'I will never be any good at this' and also the feelings which accompany such thoughts. Many of my students are unmindful of their feelings. I encourage them to become more aware of their feelings in the first instance and, on that basis, learn to deal with them.

When people 'feel good' about themselves, it seems to me, they can do most things better than when they feel bad about themselves. Thus, feelings of stress and anxiety reduce our capacity to think critically. So, instead of me giving 'critical' feedback which points to their shortcomings, I now encourage students to identify, for themselves, in the *first* instance, what they believe is good about their work – to challenge their negative misconceptions about their work – something they find more difficult than listing their shortcomings. The analysis of shortcomings is left till later.

Accounts of communities of practice make a valuable contribution to our understanding of critical thinking in organisations and cultures. On the negative side, however, such communities can reinforce *mal*practice: shared but unhelpful beliefs and activities. My students come from the public sector IS community. Part of the shared baggage they bring with them are certain negative misconceptions about their organisational world, e.g., 'there is a technical solution to every organisational problem'; 'there is just one right way to do every job'; 'End-users mess everything up' and so on. I now listen more attentively for these and encourage my students to do likewise, to challenge their own beliefs. I invite them not to learn but to *un*learn.

The research has reinforced my belief in the importance of 'doing' and 'constructing' but has made my practice more goal-oriented. I am now much more conscious of the tool-enabled critical thinking effects I am trying to bring about and the necessity for a systematic approach to supporting instructional strategies such as modelling, scaffolding and coaching.

The thesis introduced me to epistemology and ontology. My initial interest in them was pragmatic: I was interested in their practical implications for my research. Thus the epistemological question 'how do I know that to be true?' could be used as a powerful way of evaluating any research finding, including my own, or of guiding a design.

But there is far richer lesson to be learnt here. This question – 'how do I know that to be true?' – has much more general application. This question inevitably leads to a question that goes well beyond research design, to that fundamental question of our own existence, that is, the question of who I am or who I think I am? The question *how do I know to be true that I am who I think I am?* – this is roughly the question that Socrates invites the Athenians to consider and it is, is it not, close to the most revealing question we can ask about ourselves and the way that we think? When we challenge, in ourselves and in our students, thoughts such as 'I'm not good enough', 'I'm a bad reader' or 'I'm hopeless with numbers' or 'I will never achieve anything', *when we no longer* *automatically believe what we think*, then we are, paradoxically, thinking critically, and on the road to freedom, wisdom, and the good.

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APPENDICES

Appendix 3.1: The 4 COGITASKs: Instructions

MIS COURSE
CUSTOMER WEB
Designing a Customer Oriented Web site

Background

The public office or the customer counter or the reception desk were once the places where organisations met their customers. Nowadays the website is probably the commonest point of contact between any given organisation and its customer.

In this exciting exercise we will be asking you to work in groups. Each group will select the organisation of one of its members. Your task will be to design a prototype homepage and some supporting web pages for your chosen organisation.

You are free to design the page (s) anyway that you want. By all means use your imagination and have fun, but, obviously, the critical feature is that your pages should be as customer-centred as possible. In other words your customers should be able to use it easily to do the things that are important to them.

In order to do this well, you are going to have to spend some time analysing your customers requirements and planning your approach to deign of your web pages.

Tools & Technical aspects

Please do not get overly 'hung up' on the technical aspects of this exercise. Your Web page does not have to be very sophisticated. Indeed if you know how to use Word you should be able to produce a page that contains Graphics, Simple menus, Text, Navigation

Your tutor will give you what help and advice that he can as you go along so you are not on your own.

Time

Your tutor will advise you of your time

MIS COURSE

EIS
Designing an Executive Information System

Background
Select an organisation (or a large section within it) from any one the group members' organisations. Assume that a decision has been taken to install an EIS. Assume also that you and your team are responsible for the successful completion of this project from beginning to end.

In this exercise, you are essentially being asked to do two things:

- to decide on the overall structure of the EIS and what information the it should contain and
- to develop a prototype EIS which will provide and present this information.

Steps
Select an organisation and decide what kind of information this system should contain

Clearly indicate the general categories of information the EIS should contain and give examples (in each category) of some of the detailed data you would like to have at your fingertips.

Design the EIS. Decide on the software you are going to use and decide how you are gong to go about structuring it. (You may find it useful to draw a diagram indicating the overall structure of your EIS)

Develop the EIS. Develop some of the main parts of the EIS and insert sample data. You do not have bring the EIS to completion but you should give a clear indication of the overall structure and how it might work. (e.g., overall structure of components; data, functions, graphics, interrelationships between components)

The tutor will specify the time available for the exercise.

Important Note
This is not an examination! Think of it as a team effort. Your tutor is here to help you not to judge you. He is available at all times to answer questions and give advice.

Evaluate your work. When you have finished ask yourself: if I had known very little about this question prior to studying this tutorial would this have really helped me.

MIS COURSE

BPR
Re-engineering a Business Process

Background

Public sector organisations conduct much of their business by means of processes: the medical card issuance process, the planning process, the housing accommodation process, the admission and discharge process.

In this exciting exercise we will be asking you to work in groups. Each group will select the organisation of one of its members. Your task will be to select an *important* process from that organisation and to re-engineer it. At the end of the exercise you will be asked to present and justify a model/ diagram of the re-engineered process.

You are free to do this anyway that you want. By all means use your imagination and have fun, but, obviously, the critical feature is that your presentation should clearly indicate why you have chosen the process that you have and provide convincing arguments as to the benefits of the proposed re-engineered process.

In order to do this well, you are going to have to spend some time analysing your current process, its defects and its customers requirements. Be sure to challenge all assumptions.

Tools & Technical aspects
You can use any modelling tools you like but the Drawing tools in *Word* should be sufficient for your purposes.

Your tutor will give you what help and advice that he can as you go along so you are not on your own.

Time
Your tutor will advise you of your time

MIS COURSE

Online Tutorial
Designing and Developing an online Tutorial on an MIS topic

Background
The purpose of this exercise is to help you revise for your examinations but in an interesting and really useful way. You are going to be asked to compose a short electronic tutorial on some aspect of the course that (1) interests you and (2) is regularly examined. You will then share your tutorial with other MIS students and your fellow students will share their work with you. In this way you can dramatically reduce your study time as well as helping your fellow students revise their material.

Steps
Identify the module of the course in which you are most interested.

Select a topic from within that module. Identify any questions that have been asked about the topic on the examinations.

Draw a concept map of your selected topic. Indicate points and sub-points you want to include.

Design the tutorial. This design should address a specific question on the exam (and include module overview). (Draw a diagram indicating the structure of your tutorial)

Develop the tutorial. You do not have bring the tutorial to completion but you should give a clear indication of the overall structure. (Write some pages; include some links, other assets)

Evaluate your work. When you have finished ask yourself: if I had known very little about this question prior to studying this tutorial would this have really helped me.

The module tutor is available at all times to answer questions and give advice.

Complete the tutorial outside the course within a specified date.

Appendix 3.2: Sample OLD Instructions

Creating a Customer-Oriented Website: My Reflection**

Description (click to collapse)

Please reflect on what you have learned from doing this particular exercise, i.e. developing your prototype Customer-centred Website. For instance were there any specific points about the subject matter that you learned? What did you learn from working with others? In particular, what did you learn as a result of having to use a tool like *Word, Excel, PowerPoint* or *Dreamweaver* to create your artefact? In no more than 300-400 words upload your response to WebCT

**Note the instructions for each OLD discussion are the same. The only change is the name of the COGITASK.

Appendix 3.3: Internal Validity of COGITASK and OLD Methods

A comparison of COGITASK and OLD Against Campbell and Stanley's Threats to Internal Validity

Threat	Definition	COGITASK	OLD
History	Changes or events, in parallel with but other than, the treatment, may occur in the environment. Observed differences in CT performance may be better explained by these changes than by the 'treatment'	There have been no known changes in major components of the learning environment - Knowledge, Assessment, Learner or Community, (KLAC)-since the beginning of the research	Students recorded OLD contributions immediately after the COGTASK. Thus the validity of their comments cannot be affected by any intervening events
Testing & Sensitising	Repeated exposure to testing can lead to the sensitising of subjects to the test. Observed differences in CT performance may be better explained by sensitisation effects than by the 'treatment'	Each COGITASK is a different task.	Since the OLD instructions are almost identical there is a possible sensitising threat. However the fact that long intervals of 6-8 weeks separate each administration of the method are likely to offset any possible sensitising effect (NB: A trade off is required: to avoid the instrumentation threat (see below) one exposes oneself to the testing threat)
Instrumentation	Changes may take place (over time) in the test itself. Observed differences in CT	The COGITASK instructions vary little from one administration of the test to the next. .(	The OLD instructions are almost identical for each administration of OLD

	performance may be better explained by these changes in the test than by the 'treatment'	Each task, though different, tests for certain cognitive and technical skills and knowledge in common with other tasks)	
Mortality	Individual subjects may drop out of the research. Observed differences in CT performance may be better explained by these drop-out effects than by the 'treatment'	The study is confined to those who remain (at any rate, There are few drop outs from the program.) The COGITASK is based on group not individual scores, thus it is less vulnerable to this threat than other studies	The study is confined to those who remain (at any rate, There are few drop outs from the program.) Those who complete COGITASK automatically complete OLD.
Maturation	Changes in the subjects general development may occur in parallel with the treatment. Observed differences in CT performance may be better explained by these changes in attrition rates than by the 'treatment'	Do not attempt to 'control' for this but be alert to possible effects	Do not attempt to 'control' for this but be alert to possible effects
Selection	Subjects are not selected randomly. Inferences, based on statistical tests, are invalid.	NA The study is not a fixed explanatory study. It does not require random selection of subjects to test hypotheses based on inferential statistics. The study, and COGITASK, uses exploratory data	NA The study is not a fixed explanatory study. It does not require random selection of subjects to test hypotheses based on inferential statistics. The study uses TEXTUAL analysis & exploratory data

		analysis not inferential/ confirmatory analysis. The study generalise to a theoretical domain not to a population	analysis not confirmatory analysis. The study generalise to a theoretical domain not to a population
Causal ambiguity	Where there is a complex interrelationship of causes (mechanisms) at work, the researcher erroneously concludes that X is the cause and Y the effect, when in fact the opposite, or some other causal relationship, is the case	The study, generally, presupposes that causal ambiguity is a necessary premise of the investigation and that such ambiguity is unavoidable.	The study, generally, presupposes that causal ambiguity is a necessary premise of the investigation and that such ambiguity is unavoidable.
Setting	The setting of the study is context-bound that it makes it impossible to make useful generalisations to populations external to the study	NA The study is designed to be rooted in the context of the IPA and to explore the CT mechanisms at work in that context. Generalisation will be made to theoretical domain of Critical Thinking	NA The study is designed to be rooted in the context of the IPA to explore the CT mechanisms at work in that context. Generalisation will be made to theoretical domain of Critical Thinking

Appendix 3.4: Letter of Consent and Sample Reply

PARTICIPANT CONSENT
I have read the information provided above in the Request for Consent concerning Mr. Grogan's ED.D Thesis on Cognitive Tools and Critical Thinking and I agree to participate in this study. I have made my decision based on the information above and I have also had the opportunity to discuss the research with the author.

I understand that I may withdraw from the study at any time without adverse consequences.

Yours
XXXXXXXXXXXXXX – name anonimised by author
XXXXXXXXXX

From: Gerry Grogan [mailto:[redacted]
Sent: 08 July 2008 09:01
Subject: Request for Consent

The Relationship between Cognitive Tools and Critical thinking
Request for Consent

Introduction
At present I am completing a Doctorate in Education (Ed.D) at the University of Birmingham.

I am asking for your consent to use data which you were involved in creating as part of your studies on the MIS program.

Title of the Study
The Relationship between Cognitive Tools and Critical thinking

Purpose of the study
The purpose of the study, in very general terms, is to examine how Information Technology can help us to learn. More specifically it inquires into how electronic cognitive tools such as web-authoring packages, spreadsheets etc can help us to think more critically.

Contact no
Gerry Grogan
Institute of [redacted]

Procedures
In the course of the MIS programme which you attended (2006-2007) you created and discussed artefacts such as web-sites, tutorial and EIS models using electronic tools such as web authoring and spreadsheet tools. As part of my thesis, I would like to avail of these data as one source of data for the study.

Potential Benefits
It is hoped to use this study develop a set of practical guidelines by which electronic cognitive tools can be incorporated more widely into educational programs – of all varieties, not simply IT programs – in order to make the learning more exciting, interesting and challenging. Ultimately, the objective of the study is to help students think more critically about issues and to apply knowledge more critically to their work.

Confidentiality
The following steps will be taken to ensure that confidentiality of any identifying information that is obtained in connection with the study.

- Data is aggregated and aggregate scores only are shown
- Data is not reported on an individual basis (No individuals will be identified)
- Pseudonyms are used
- General information about the course (Year etc) is anonymised
- Data is stored securely and password-protected

Participation and Withdrawal
You can choose to be in this study or not, or to withdraw at a later date without any adverse consequences. (Note: Discussion with the student emphasised these points and that if they withdrew, their data would be removed from the study)

Consent
If you agree to participate in the study

Please reply, as soon as possible, by email with the following text

PARTICIPANT CONSENT
I have read the information provided above in the Request for Consent concerning Mr. Grogan's ED.D Thesis on Cognitive Tools and Critical Thinking and I agree to participate in this study. I have made my decision based on the information above and I have also had the opportunity to discuss the research with the author.

I understand that I may withdraw from the study at any time without adverse consequences.

Yours

NB
Please include your name and a contact number

:

****

Appendix 4.1: MS for the COGITASK

COGITASK Marking Scheme	COGITASK:	
	Group No	
Content/knowledge	**25**	**Mark**
Lesson Objectives	5	
Main Point 1 (KRAs)	5	
Main Point 1 (KPIs)	5	
Main Point 1 (Targets)	5	
Main Point 1 (Data)	5	
Other		
Functionality: Main characteristics	30	
Summaries	5	
Hyperlinked text (Drill down)	5	
Graphics	5	
Related Topics	5	
{Any 2 of the items below}		
Quizzes/Tests (Dynamic Input)	5	
Searching/Enquiry	5	
Examples	5	
Other		
Structure & Construction issues	25	
Construction 1		
An overview of the overall design	5	
No. of design levels	4	
Beginning-End	4	
Construction 2		
Menu inc. Hyperlinked Menus Navigation links: Back/Home/Next Ease of use (to find ones way around) Other	4 4 4	
Layout	20	
Sheet Title and Headings 4	4	
Menus 4	4	
Data 4	4	
Navigation placement (Home/Back/Next) 2	2	
Related Links (Formulae + Assumptions + Macros 2) 2	2	
Graph Area 2	2	
Other (Areas that cannot be overwritten 2) 4	2	
Grand Total		

Appendix 5.1: Codebook

Critical Thinking and Cognitive Tools
Online Discussion (OLD) Transcripts
Codebook

Introduction

Online Discussions (OLD) were selected as a data collection method in the author's research. This Codebook is designed to support the coding of the transcripts of these discussions. The book sets out the categories, subcategories, names, descriptions/definitions, examples and indicator words for each code. It also sets out rules to guide the coding process. The purpose of the Codebook is to reinforce the reliability of coding

The Codebook has been written primarily to support the author's coding, but should be suitable, also, for any third party who wishes, with appropriate training, to replicate the coding. The Codebook is designed to be consulted repeatedly in the course of coding.

The Codebook contains the following material:

- General Definitions
- List of categories, subcategories, names, descriptions/definitions, examples
- Rules for Coding and Cross Checking

General Definitions

The Recording Unit/ (Unit of Analysis): the unit (i.e., segment of text) to be used for coding (e.g., word, phrase, sentence). The Recording Unit in this coding scheme is the sentence. ‘Statement’ is synonymous with sentence.

Indicator word: Indicator words are words which are often associated with a particular code. Thus ‘frustrating’ is a word indicative of a code named ‘individual issues and feelings’

Cross check query: A database (SQL) query exists for each code. This generates a list of statements which might be expected, solely on the basis of indicator words, to have been assigned a given code but, in fact, are *not*. These are called *exception statements.*

List of categories, subcategories, names, descriptions/definitions, examples

Categories
There are three categories: Metacognitive Factor, Orientation and Statement Type.

A category is made up of sub categories. The categories and subcategories are listed in the table below

Category Name	**Subcategory Name**	**Code**	**Description of code** (*A statement is assigned to this code if it describes or explains or refers to.)*
Metacognitive Factor			
	Task	T	Knowledge or beliefs about the Task (including the tools used)
	People	P	Knowledge or beliefs about the People (including oneself)
	Strategies	S	Knowledge or beliefs about the strategies adopted, both cognitive and metacognitive
	Other	O	None of the above
Orientation			
	Positive	P	an explicit or implicit favorable mention of some occurrence/ experience
	Negative	N	an explicit or implicit unfavorable mention of some occurrence

	Neutral	X	A statement in which there is no discernible orientation (often purely descriptive)
Statement Type			
	Reflective	M	Knowledge or beliefs that focus on Reflecting generally or describe/ demonstrate a metacognitive awareness of any aspect of the experience.
	Learning	L	Knowledge or beliefs that analyse and focus explicitly on lessons learned, either general or specific lessons, both in terms of content and process.
	Evaluation	E	Knowledge or beliefs that analyse and focus on Evaluating the effectiveness of the performance on the Task both in terms of end-result and process. It might also refer to specific outputs of a solution such as BPR process.

Subcategories and Coded Items
A sub category may be made up of coded items. This only applies to the Metacognitive Factor subcategories. For each coded item the table below lists the name, code, description, examples and indicator words. Indicator words are words which are often associated with a particular code.

Metacognitive Factor Subcategory Coded Items

Task				
Coded Item Name	**Code**	**Description**	**Example(s)**	**Indicator Words**
Task_Difficulty	T01	a task is perceived to be difficult or not.	*At first I thought this to be a formidable challenge having little knowledge in this area* *I found the task that beset our group to be quite a challenge*	Difficult, challenging, easy,
Task_description	T02	A general description of how one found the task e.g. interesting, worthwhile, useful, etc This does not include statements which describe the task as 'enjoyable' (P01) or 'difficult' or easy (T03)	*I found this exercise on the planning and creation of an EIS very worthwhile* *It was an interesting exercise, and it was good to get the views of people in different jobs and in different counties*	Exercise

End Result	T03	The purpose of the task but most especially success or failure in relation to task purpose including both the Content and the Appearance/Finish of the artefact	*I think we did well to analyse, research and develop the prototype website within the two and a half hour deadline we had.* *I think our group accomplished the task as best we could using the model of management and customer orientation that we had discussed the day before.*	Objective, task, end result, end product, goal, achieve, accomplish This code is closely related to Evaluation statement Type
Tools_Ease_ofUse	T04	The degree to which The features or mechanisms of a tool or technology are perceived to be easy to use	*We used Frontpage Express which is a smaller version of the large Microsoft web design application which is very easy to use.*	Ease of use, unwieldy, develop, Package, software, web, web(page) Mention of any tool by name: PowerPoint, Dreamweaver, Frontpage, MS Word, Excel.
Tool usefulness	T05	The degree to which The features or mechanisms of a tool or technology are perceived to be useful	*the use of MS Word to build the web page allowed us to demonstrate the fruits of our labour* *MS Word restricted*	Useful, function, uses, Package, software, web, web(page) Mention of any tool by name:

			some of our ideas as a certain portion of what we would have liked to have included in the finished article was not possible due to the lack of appropriate software	PowerPoint, Dreamweaver, Frontpage, MS Word, Excel.
Other_Context_Task	T09	None of the above but might include An (external) set of conditions or factors which exerts a favorable or unfavorable (problem, difficulty or constraint) influence on the Task in some way	*Gerry advised us that the fact that no one in the group had a working knowledge of HTML / Dreamweaver would not be a problem as the creation of a web page from MS Word would suffice.*	

People				
Individual issues	P01	Individual issues & feelings (of enjoyment, interest, usefulness or boredom, frustration in relation to the task)	I found the exercise on the creation of a customer centred website very interesting and informative. The creation of a customer-orientated website was a very enjoyable experience.	Enjoyable, frustrating, reassuring 'mixed feelings', anxiety, apprehension, delight
Teamwork	P02	A strength or a weakness of the group	A problem we encountered was that there was no person in our group with any experience of creating a web site from scratch The design layout was a result of collaboration between all team members and the multitude.	Weaknesses Limited, lack, problem, experience, expertise, skills. Collaboration, teamwork, together, communication, other(s), other people, 'pulling together', member, participate, skills
Other_context_people	P09	None of the above but might include an (external) set of conditions or factors which exerts a favourable or unfavourable (problem, difficulty or constraint) influence on the people in some way.		Tutor, classroom, lab, instructions

Strategy				
Application of knowledge	S01	The direct application of a some piece of knowledge This might also include a description of the domain area or process to which a technique or tool is being applied eg an eis is a ….	I found that the practical application of the socio technical model really brought home to me what i had learned from lesson one Looking at the value chain, we also focused on adding value to the site Our topic was based on a bpr and how we could show …our way of educating others as to what a bpr was.	Mention of any of the following concepts (e.g. Value chain, customer needs, bpr, eis/dss) Apply, benefit, practice/practical, model Topic, subject, This code is closely related to learning statement type
Reasoning	S02	Any critical factor determining approach, content or layout of artefact, (includes analytical method or technique used brainstorming, flow diagram, making a list, flip chart, de bono's six hats)	As a result, team members were involved in all aspects of the website – both the content and design. a key element in our design was always the customer, and what we could do make the experience of using the site easier for the user.	Since, as a result of, therefore, thus, first, then key because, looking at = analyse, decide, based on, imperative, given that, keep in mind, main point

Planning and control	S03	Two self-regulatory or metacognitive processes, namely planning & controlling only	it has also given me a very useful insight into time management and customer focus. it helps to identify where we might be falling down on things	Plan(ning), check(ing), control, manage time, practical application, objectives, constraint, limit, research,
Organising	**S04**	Three self-regulatory or metacognitive processes, namely organizing, directing & coordinating (inc. Researching)	Following on from the tutorial the group leader decided, that as well as focusing on the task that we also needed to focus on our resources	Organise, resources, divide, division of labour, leader, role, allot, group
Other_context_strategy	**S09**	None of the above but might include an (external) set of conditions or factors which exerts a favorable or unfavourable (problem, difficulty or constraint) influence on the strategy in some way but does not fit into one of the above categories.		

Category: Orientation

Orientation refers to the general attitude expressed in a statement. For each coded item the table below lists the name, code, description, examples and indicator words..

Name	Code	Description	Example (s)	Indicators
Positive	**P**	An explicit or implicit favorable mention of some occurrence/ experience	I found the exercise on the creation of a customer centered website very interesting and informative.	Happy, good, great, enjoy Beneficial, valuable, interesting, help, useful, worthwhile, insight
Negative	**N**	An explicit or implicit unfavorable mention of some occurrence/ experience	initially there was some disarray and bewilderment as to how we would proceed.	Unhappy, bad, tedious, boring, useless
Neutral	**X**	A statement in which there is no discernible orientation (such statements are often purely descriptive)	As a small group we put all heads together and came up with a property-based homepage. We divided into 2 groups.	

Category: Statement type

Statement type refers to the focus of the statement. There are three foci: Reflective, Learning and Evaluative. A statement of any type may relate to Task, People or Strategy. For each coded item the table below lists the name, code, description, examples and indicator words.

Name	Code	Description	Example	Indicators
Reflective	M	Knowledge or beliefs that focus on reflecting generally or describe/demonstrate a metacognitive awareness of any aspect of the experience.	*It's very important who you have working on the project* *The time limits on the project meant we had to follow a project plan ensuring we didn't run out of time designing the webpage*	Very many
Learning	L	Knowledge or beliefs that analyse and focus explicitly on lessons learned, either general or specific lessons, both in terms of content and process.	*Having completed this exercise, creating an on-line tutorial, I have learnt many valuable things.* *From what we learned the previous day I have a better understanding of how the socio-technical model of organisations work.*	learn, understand it highlighted, it shows
Evaluation	E	Knowledge or beliefs that analyse and focus on Evaluating the effectiveness of the performance on the Task both in terms of end-result and process. It might also refer to specific outputs of a solution such as BPR process	*The end product was Customer focused, delivering what we identified as what the customer needed* *Working as a team, with X as team leader and Y, I felt that we worked very well together.*	Good/ bad Success/ fail Achieve/ accomplish Benefit

Rules for Coding and Cross checking

Coding Rules

1. Familiarize yourself thoroughly with the data in this Codebook
2. Each statement must be assigned a code (-set) and one only
3. Always code the main point of the statement. Code quickly
4. Where a statement contains two segments/clauses (conjoined by 'and' for instance) which relate to different code-sets, assign the code to the first segment of the sentence only

   We worked well together and assembled a well presented tutorial on Business Process Re-engineering, developed using Microsoft PowerPoint.

   We worked well together is the segment to be coded. It is assigned P02 – Teamwork

5. Code in context. For instance, if necessary, draw a reasonable inference about the meaning of statement 2 from statement 1 and statement 3.
6. If you are having difficulty assigning a code to a statement – Check statement for the presence of indicator words
7. Assign any statement to the Code 'Other' if you are still unsure about its classification

Cross checks

8. Cross check for consistency each batch of 50 coded items by running the cross check queries
9. A database cross check query exists for each code. This generates a list of *exception* statements which might be expected, solely on the basis of indicator words, to have been assigned a given code but, in fact, are *not*. Run the cross check queries for each code. Examine each *exception* statement. Determine if there is a good reason for the code assigned does not conform to the expected code. Recode any statement as necessary. (E.g. feeling and I feel)

   This statement was originally coded **S01** – Application of Knowledge.

   I found this exercise very interesting and informative as it brought together in a very practical way the information in the notes

   The cross check query suggested it might be **P01** – Individual Issues. However further examination of the statement shows that the original S01 code is correct because (1) the main point of the statement is knowledge application and (2) the use of the word 'interesting' here has nothing to do with an emotional response. See immediately below.

10. Be careful with certain words such as 'feeling', or 'interesting'. While these are indicative of P01 codes, they may, in fact, be used synonymously with words for thinking.

I feel our end result was exactly the type of product that .. our client was looking for.

NOT **P01** code. This is coded as **T03**- End Result, as the main point of the statement (see above) concerns achieving the objective not any emotional reaction. Feel is being used as a synonym for ‘think’

Appendix 5.2: Krippendorf's Six Questions applied to the OLD.

Which data are analyzed?	On line discussion data, completed by the use of a password-protected electronic cognitive tool. Not voluntary a narrative account of the students' reflections on their performance on the COGITASK indirect evidence in the form of self-reported, 'soft' or 'subjective' data on students *perceptions* of their critical thinking performance provide insights into how the use of electronic cognitive tools can facilitate certain critical thinking mechanisms especially metacognition Data not private. It is available for all on the discussion forum.
How are they defined?	Each item of data can be uniquely defined by the ID of its creator and the ID of the Cogitask OLD is an individual task
What is the population from which they are drawn?	Drawn from the population of MIS students MIS students are part of the population of accredited programs They can not be treated as random samples from either population
What is the context relative to which the data are analyzed?	OLD forms a natural part of their learning since MIS students are asked to contribute to some 20 such discussion tasks in other parts of their course (Greenlaw & DeLoach 2003:36) The OLD forms a natural part of student leaning. It is completed in the classroom, immediately. after the completion of the COGITASK Student-subjects construct an artefact from which the researcher deduces their thinking

	Student subjects talk about the construction of that artefact, in other words, they record their *thoughts* Knowledge not competence Construction not co-construction The data are analysed in conjunction with the COGITASK Data provide data on students opinions about their performance Data are analyzed both quantitatively and qualitatively Data is used to provide answers to some questions raised in the COGITASKs analysis or to some hypotheses advanced additional data on the extent to which CT is evident in their written communications and what is the relative distribution (frequencies) of those classes Data is used to compare actual performance with their view of actual performance To classify their opinions by tool, group, COGITASKs
What are the boundaries of the analysis?	
What is the target of the inferences?	The inferences will be drawn for the domain of critical thinking and not for any one student group

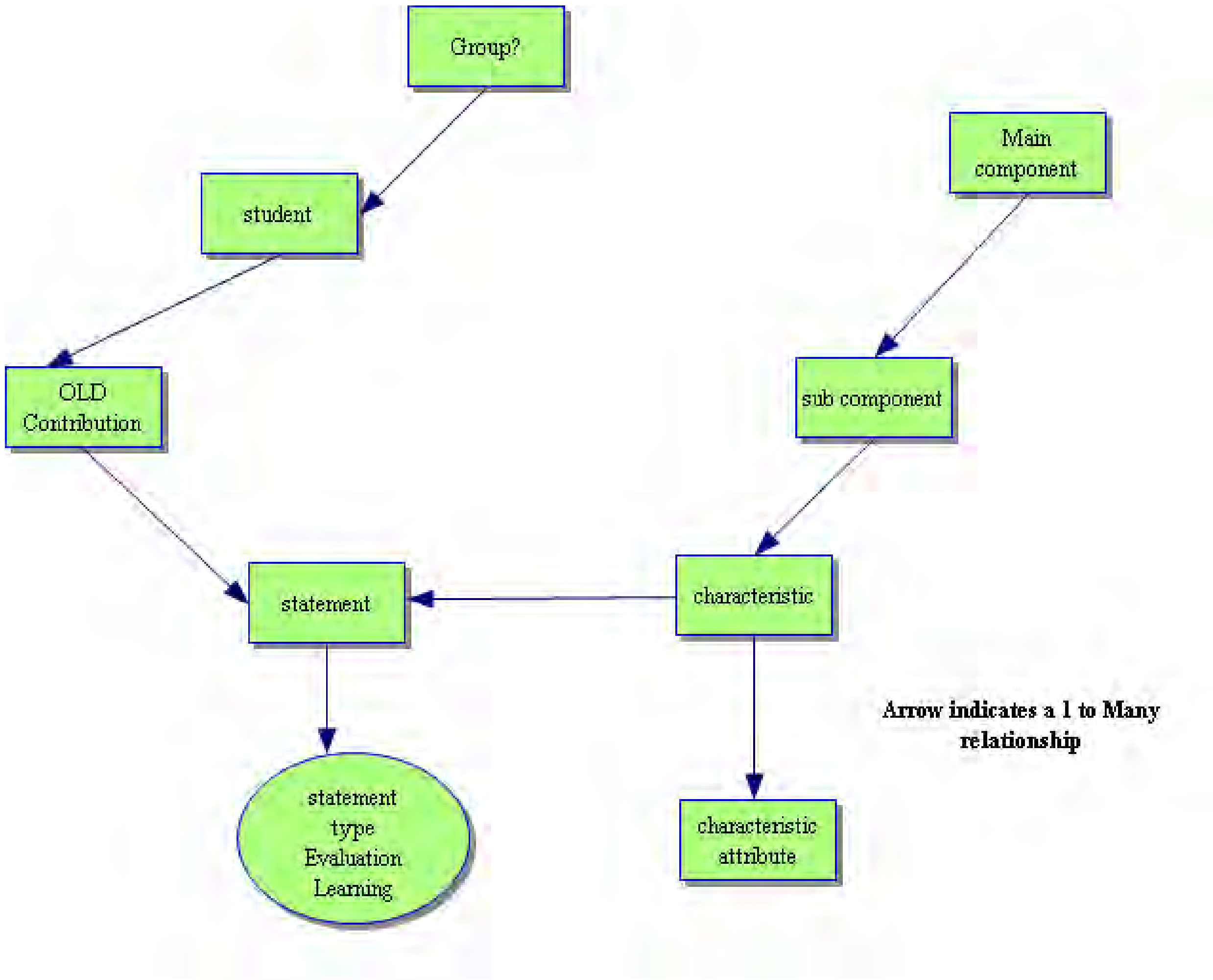
Appendix 5.3: Coding Procedure

Coding procedure
The Generation of Verb Clusters

Main steps

1. Generate the frequency distributions of all words
2. Isolate key verbs with *f(s)* of 5 or more (the emergent verb clusters)
3. In the verb cluster include all non-verb words related in form to the verb eg think (*vb*), thought (*n.*)
4. Identify all synonyms of the verb (Merriam Webster)
5. Include in the verb cluster all synonyms of the verb and their related words eg construct, build, built, building
6. Review
7. Resolve overlaps
8. Finalise the cluster
9. Count total number of occurrences for each cluster
10. Construct a frequency distribution.

Appendix 5.4: Entity Model of Coding Structure



Entity Model to show Coding Structure Extract Only

Appendix 6.1: Summary of Findings

Table A6.1: Summary of Consolidated Findings in Relation to Research Questions 1 & 2.

Theoretical Framework Related aspect	**Findings: strengths and weaknesses, based on COGITASK data**	**Findings: strengths and weaknesses, based on old data**
	Strengths	
Constructive	Students are reasonably good at the synthesising aspects of the task - assembling components/ideas into artefact The constructed artefacts worked A strong orientation towards the importance of construction (rather than towards analysing and planning)	Strong focus on achieving the end result Teamwork is seen as a key strength A strong orientation towards the importance of construction (rather than towards analysing and planning)
Cognitive	Students do a reasonable job at applying their understanding. This is especially the case where the application involves descriptive elements, or is familiar in some way or the requirement is well understood (use of graphics, summaries and examples)	Students recognise the importance of applying Students do apply higher order cognitive skills such as applying, analysing and evaluating but are better at applying lower order cognitive skills such as remembering and describing. Students are reasonably good at applying domain specific

		concepts [general knowledge most often refers to ‘know how’, learning how to put ideas and concepts into practice. ‘putting into practice’ is seen as being critical to getting meaning out of their experience]
Metacognitive		Their general assessment of their successes and the reasons for it is fairly accurate Have a reasonably good knowledge of the importance of other people and teamwork Have a reasonably good knowledge of the importance of cognitive strategies
Knowledge	Students perform best on the content/knowledge feature esp. Factual knowledge	Students learn both domain specific and general knowledge. Domain specific concepts include value chain, customer focus and analysis of customer needs, technical knowledge such as graphics and websites. General knowledge most often refers to ‘know how’, learning how to put ideas and concepts into practice. ‘putting into practice’ is seen as being critical to getting meaning out of their experience.
	Weaknesses	
Constructive	The artefacts constructed lacked professional finish.	Perhaps the importance of achieving the end result is emphasised at the expense of analysis, process and metacognitive issues

	Underdeveloped orientation towards analysing and planning	Lack of technical skills
Cognitive	Students perform worst on the functionality feature, which suggests an underdeveloped ability to apply what they know to authentic tasks and contexts Understanding can be shallow and application of knowledge often lacking in depth. Students perform very badly on indicators of depth such as the drill down item and no. Of design levels item The analysis of the overall design is frequently inadequate	The application of their knowledge is can be overly broad and superficial Can apply higher order cognitive skills but have difficulties with them Evaluation accounts tend to lack balance
Metacognitive		Students metacognitive knowledge and awareness is under-developed Their metacognitive knowledge appears to be somewhat lacking in depth, their accounts of their own performance often tend towards the superficial (the metacognitive tendency to the superficial parallels the cognitive one) Students can be somewhat blind to their own misconceptions and weaknesses or misdiagnose their causes Knowledge of metacognitive strategies is underdeveloped

		Underdeveloped processes of metacognitive control such as planning, organising and controlling. Strong tendency to describe their experience (e.g., their metacognitive strategies) rather than reflect on it or analyse it(the metacognitive tendency to the descriptive parallels the cognitive one)
Knowledge	Students perform less well on conceptual knowledge	The application of their knowledge is somewhat superficial

Appendix 6.2: Summary of Eight Possible Critical Thinking Effects and Related Mechanisms

Findings: Strengths & Weaknesses	**The tool-enabled effect**	**Technical Mechanisms**	**How does the tool mechanisms explain the Findings (e.g., support a strength or expose the weakness)**	**Specific Examples of how mechanism enforces/activates some cognitive process**
Constructive				
reasonably good at the **synthesising** aspects of the task –	**Tools can provide a technical framework which scaffolds construction**:	Overall technical Framework	Tools provide an overall technical framework (consisting of a structural framework and a procedural framework) upon which students can 'hang' their constructs and synthesise components. In order to avail of the technical framework, students must, however, have a conceptual framework to align to it. Thus the technical framework encourages students to develop such conceptual frameworks	Examples of Predefined structural framework =: Database- Table-Field; Book-Sheet-Cell,
strong orientation towards construction		Predefined Core Structure, Templates	The structural framework (e.g. database structure) consists of technical components (database, table, record, field). This structure provides a shell which supports the	The core structure of a database, for instance, provides a framework

			student constructing. The framework acts as a mechanism that synthesises components of the construct into a coherent whole.	without which database construction would be very difficult. It points the student to the necessary data components and it provides mechanisms, ‘relationships’, to enforce the synthesis of the component parts into a coherent database.
focus on achieving end result artefacts worked		Predefined Sequences (e.g., Wizards Subtotals Consolidation) Express tools	The procedural framework synthesises construction tasks along a predefined sequence of steps or procedures, thus increasing the probability that the resultant artefact functions correctly. Procedural frameworks encourage users to (1) consider all conceptual framework’s components (2) to impose consistent structure or form on the component data and (3) to execute the task in the appropriate sequence. The procedural framework scaffolds the production	For instance the ‘Chart wizard’ is a predefined sequence which scaffolds the construction of graphs. It steps novices through the sequence of actions required to construct a graph (and in the process provides

[Teamwork is seen as a key strength]			of 'professionally'-finished artefacts. Thus, the framework scaffolds the artefacts functionality, form and finish.	information on conceptual components)
The artefacts constructed lacked professional finish – (partly because of underdeveloped orientation towards analysing and planning) achieving the end result is emphasised at the expense of analysis, [reasonably good at the **synthesising** aspects of the task – artefacts worked strong orientation towards construction]	**Tools can support Analysis and Synthesis**	Menus Navigation Hyperlinks Multiple components	The tool highlights the need for the student to (1) *analyse*/ conceptualise task into conceptual components (2) align these conceptual components to separate tangible technical components. Students are required to be clear on the *meaning* of each of the conceptual components if they are to correctly assign each to its corresponding technical component.(ref) (3) link/ *synthesise* separate technical components into an overall structure The technical processes of analysis supports the cognitive process (1) by analysing and representing logical concepts as technical components, The technical process of synthesis parallel the cognitive process by reinforcing internal schematic	For instance, The Menus and navigation mechanisms can only be used if the student has already analysed the artefact into **components** and transformed these into component pages (which can be navigated to)

			organisation building links between components and synthesising them into coherent, external technical structures such as artefacts. The artefact is an external representation of the degree to which knowledge has been synthesised.	
Cognitive				
reasonably good at applying domain specific and general procedural knowledge which most often refers to 'know how', learning how to put ideas and concepts into practice. do apply higher order cognitive skills but better at applying lower order cognitive	**Tools can facilitate the application of conceptual knowledge and higher order thinking;**	All tool mechanisms	To use tools is, by definition, to apply procedural knowledge. Application of procedural knowledge, however, encourages students to revisit their conceptual knowledge (especially the case when students encounter some 'technical' problem or some exception to the rule or some new context.) any non-trivial, authentic, tool-based task orients students towards engaging in higher order learning activities such as applying, analysing, evaluating and creating.	The Design of a Customer Oriented website, requires students to engage in higher order thinking and to apply to an authentic context, (1) procedural knowledge (style sheets, images sizing etc) and (2) conceptual knowledge ('segmentation' 'customisation') about customers into concrete form .
Understanding can be shallow and	**Tools Can facilitate the**	Hyperlinks	(1) The conceptual components in a domain may often be vertically	The hyperlinks mechanism can

application lacking in depth. Low scores on indicators of depth Drill Down item and No. of Design Levels item The analysis of the Overall design is frequently inadequate	**Deepening of Understanding**	All hierarchical tool structures: Book-Sheet-Cell linked formulae Multi-level sorting Pivot tables Subtotals	ordered into conceptual levels (2) Tool components, also, operate at varying vertical, technical levels of depth (3) Tool components are linked in a hierarchy of levels by means of hyperlinks. Hyperlinks can be used to drill down, progressively deeper, between these levels of depth (4) To each of these technical levels conceptual levels can be assigned. Tool components ordered in levels, encourage deeper approaches to learning since they invite the student to make *conscious* decisions about conceptual levels in the task and to *explicitly* assign these to the tool component-level.	only be used if the student has already analysed the artefact into (1) its separate components and subcomponents and (2) determined the hierarchical relationship between these components (component level)
Metacognitive				
metacognitive knowledge under-developed blind to their own misconceptions and weaknesses or misdiagnose their causes	**Tools can Expose Weaknesses in Critical Thinking**	Error messages Dynamic versions	Tools expose, by means of error messages, possible weaknesses in all four aspects of critical thinking, constructive, cognitive, knowledge and metacognitive. Operationalising concepts through authentic tool-based tasks exposes misunderstandings and imprecision in conceptual knowledge.	The error message mechanism halts the application and presents a visual/audible signal. The application can only resume if the user analyses the error and attends to it

underdeveloped processes of metacognitive control.			Weaknesses in metacognitive control, such as failures to regulate the task, become apparent in the design *process* that surrounds the creation of any tool-based artefact. Dynamic versions provide insights into the construction *process* over time and allow students the opportunity to test their artefacts.	
students can be somewhat blind to weaknesses (Weakness) reasonably good at the **synthesising** aspects of the task – but weak on analysis [a reasonably good knowledge of the importance of other	**Tools can make critical thinking more visible**	Homepage Main Menu [Other mechanisms include subtotals outlining] Homepage Main Menu	Humans habitually resort to tools to represent problems that they cannot solve in their heads. In so doing, they externalise their thinking and make it visible. This helps to make any weaknesses (blind spots) in it visible Tools make the abstract concrete and therefore visible. Some mechanisms such as the Homepage or the Main Menu provide a visible summary of thinking (both analysis and synthesis) at a glance. The tool-based collaborative process makes thinking visible because thinking is externalised through	For instance, When an abstraction such as a 'vision of customer service' assumes a 'concrete' form in an organisation's website, the characteristics of the abstraction become visible. The thinking is visible at different levels. For example it is visible at summary level, such as a

people]			social interaction and discourse.	Homepage, at page and object level .
Knowledge				
perform best on the Content/Knowledge feature esp. factual knowledge learn both domain specific and general knowledge. General knowledge most often refers to 'know how', learning how to put ideas and concepts into practice.	**Tools can facilitate the natural acquisition of all Knowledge types (factual, conceptual, procedural)**	The Core Tool structure Database Design – Datasheet order of task elements	In authentic tool-based tasks, knowledge factual, conceptual, procedural; general and domain specific is acquired in the natural context through its application to meaningful, authentic tasks Different phases of the tool-based tasks may require different tyres of knowledge. Knowledge is acquired at the natural time, in the natural order as the need arises. The tool enforces the order of the task elements The tool tacitly embodies the factual, conceptual and procedural knowledge - general and domain specific- central to the overall knowledge framework of the domain. The chart wizard, for instance, embodies - general and domain specific conceptual and procedural knowledge about graphs.(ref) Such tacit embodiment invites the student to internalise the knowledge	The Pivot table mechanism provides cross-tabulations of data sets. It enforces the order of the task elements. It can only be used if the student has already completed the following task elements: conceptualise the problem, organise the **data,** sort it according to a specific key, and lay out cross tabulating variables (fields) in preordained columns and in preordained rows,

			as one's own knowledge framework	assigning data items to a data area.
General knowledge most often refers to 'know how', learning how to put ideas and concepts into practice. 'Putting into practice' is seen as being critical to getting meaning out of their experience	**Tools can facilitate Meaning-Making**	All tool mechanisms	The tool facilitates meaning-making by the transformation of the abstract into the concrete The tool has technical components, the task has conceptual components. Students are forced to be clear on the *meaning* of each of the conceptual components if they are to correctly assign each to their corresponding technical component. Where students are unclear, however, about meaning, one way the tool exposes their misconceptions as incorrect assignments of the conceptual to the technical The tool facilitates first hand experience, subjective knowing of what things *mean* and in so doing encourages individual perspectives on meaning	The Design of an EIS requires students to operationalise 'theoretical' or logical concepts such as key result areas, indicators, targets, action plans; thereby gaining direct first hand understanding of what these concepts *mean* in practice.

Appendix 7.1: A summary of Tool-enabled critical thinking effects and Broad Instructional Precepts Designed to Support those effects

The tool-enabled effect	Technical Mechanisms	How does the tool mechanisms explain the Findings (e.g., support a strength or expose the weakness)	Broad Precept
Tools provide a technical framework which scaffolds construction:	Overall technical Framework	Tools provide an overall technical framework (consisting of a structural framework and a procedural framework) upon which students can 'hang' their constructs. In order to avail of the technical framework, students must, however, have a conceptual framework to align to it. Thus the technical framework encourages students to develop such conceptual frameworks	6. Devise authentic, construction tasks using authentic tools which encourage students to avail of the tool's technical framework 7. Model appropriate tool use, especially the 'knack' of exploiting the technical framework and similar 'tricks of the trade'
	The Core Tool Structure Templates	The structural framework (e.g., database structure) consists of technical components (database, table, record, field). This structure provides a shell for the student constructing. The framework acts as a mechanism that synthesises components of the construct into a	8. Provide ongoing coaching on all aspects of construction

	Predefined Sequences (e.g., Wizards Subtotals Consolidation) Express tools	coherent whole. The procedural framework synthesises construction tasks along a predefined sequence of steps or procedures, thus increasing the probability that the resultant artefact functions correctly. Procedural frameworks encourage users to (1) consider all conceptual framework's components (2) to impose consistent structure or form on the component data and (3) to execute the task in the appropriate sequence. The procedural framework scaffolds the production of 'professionally'-finished artefacts. Thus, the framework scaffolds the artefacts functionality, form and finish.	9. Scaffold student construction by the use of procedural frameworks 10. Align assessment criteria for authentic tasks to the authentic criteria of the community of practice, relating such criteria to form, functionality and finish
Support Analysis and Synthesis	Menus Navigation Hyperlinks Multiple components	The tool highlights the need for the student to (1) *analyse*/ conceptualise task into conceptual components (2) align these conceptual components to separate tangible technical components. Students are required to be clear on the *meaning* of each of the conceptual components if they are to correctly assign each to its corresponding technical component. (ref)	1. Devise authentic 'design and make' tasks that contain non trivial analytical as well as synthetic requirements 2. Provide coaching especially on the designing/analytic parts of the task

		(3) link/ *synthesise* separate technical components into an overall structure The technical processes of analysis supports the cognitive process (1) by analysing and representing logical concepts as technical components, The technical process of synthesis parallel the cognitive process by reinforcing internal schematic organisation building links between components and synthesising them into coherent, external technical structures such as artefacts. The artefact is an external representation of the degree to which knowledge has been synthesised.	3. Scaffold students in the making/synthetic parts of artefact construction 4. Encourage students to synthesise all their work- e.g., objects produced in the process of artefact creation (plans, prototypes, artefacts, analytic diagrams/models, notes, reflections, online discussion texts) might be synthesised in electronic in portfolios. 5. Develop assessment criteria relating to both analysis and synthetic elements of construction
Tools can facilitate the application of conceptual	All tool mechanisms	To use tools is, by definition, to apply procedural knowledge. Application of procedural knowledge, however, encourages	**1.** Devise non-trivial, authentic tasks which focus on 'applying' to produce artefacts (e.g. building website, making a video) rather than paper-based application (an essay)

knowledge and higher order thinking		students to revisit their conceptual knowledge (especially the case when students encounter some 'technical' problem or some exception to the rule or some new context.) any non-trivial, authentic, tool-based task orients students towards engaging in higher order learning activities such as applying, analysing, evaluating and creating	**2.** Provide multiple examples and models of how to apply the tool to different contexts and encourage students to apply their knowledge to a wide range of contexts **3.** Scaffold certain higher order skills (eg with templates: evaluating- cost benefit template) **4.** *Prior to construction*, require students to revisit and apply their conceptual knowledge 'on paper' (produce as a deliverable a formal conceptual analysis such as a customer profile or a customer needs analysis or an MBO guide) **5.** Assess for application of both higher order skills and procedural and conceptual knowledge
Tools Can facilitate the Deepening of Understanding	Hyperlinks All hierarchical tool structures: Book-Sheet-Cell linked formulae Multi-level sorting Pivot tables Subtotals	(1) The conceptual components in a domain may often be vertically ordered into multiple conceptual levels (2) Tool components, also, operate at multiple vertical, technical levels of depth (3) Tool components are linked in a hierarchy of levels by means of hyperlinks. Hyperlinks can be used to drill down, progressively deeper, between these levels of depth (4) To each of these technical levels conceptual levels can be assigned. Tool components ordered in levels, encourage deeper approaches to learning since they invite the student to make *conscious* decisions about	1. Design multi-level tasks, that encourage deep approaches to learning and depth of understanding. 2. Model with multiple examples the concept of depth and drill down as applied to tool-based artefacts 3. Scaffold students' deep approaches to learning and depth of understanding by encouraging them to lean on the technical framework **4.** *Prior to any construction*, require students to produce a representation of levels of progressive depth and links,- the hierarchy of levels- indicating the locus of their drill downs. eg an entity-relationship diagram 5. Develop assessment criteria for depth of

		conceptual levels in the task and to *explicitly* assign these to the tool component-level.	understanding: that require students to consider the number of design levels in task/problem using examples such as diagnosis of a concatenation: e.g. equipment breakdown , multi-layered organisational problem.
Tools Expose Weaknesses in Critical Thinking	Error messages Dynamic versions	Tools expose, by means of error messages, possible weaknesses in all four aspects of critical thinking, constructive, cognitive, knowledge and metacognitive. Operationalising concepts through authentic tool-based tasks exposes misunderstandings and imprecision in conceptual knowledge. Weaknesses in metacognitive control, such as failures to regulate the task, become apparent in the design *process* that surrounds the creation of any tool-based artefact. Dynamic versions provide insights	1. Devise tasks that explicitly include metacognitive goals (tasks of sufficient complexity that allow for meaningful reflection (on errors, strengths, weaknesses) and meaningful regulation of a process) 2. Model problem solving especially the systematic analysis of error messages or what to do when one encounters a blockage or ‘exceptions to the rule’ and tackle the misunderstandings that often surround these. 3. Make students aware of the key concepts of metacognition etc 4. Coach students on process aspects of task especially, planning and management of time.. 5. Develop assessment criteria, targeting metacognitive knowledge and metacognitive control, process and product

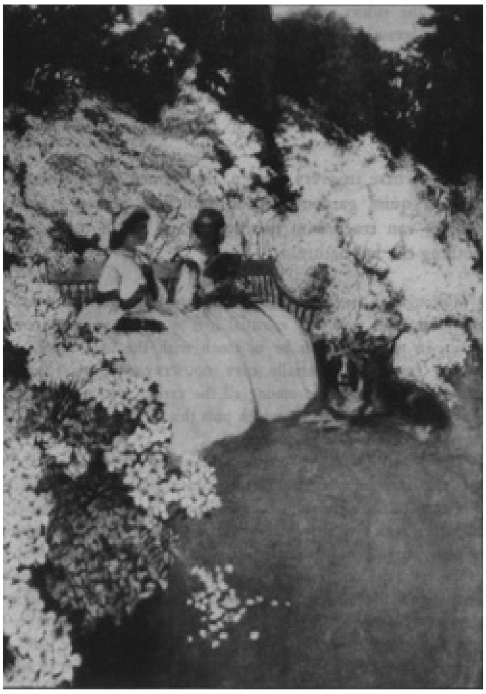
		into the construction *process* over time and allow students the opportunity to test their artefacts	
Makes critical thinking visible	Homepage Main Menu [Other mechanisms include subtotals outlining] Homepage Main Menu	Humans habitually resort to tools to represent problems that they cannot solve in their heads. In so doing, they externalise their thinking and make it visible. This helps to make any weaknesses (blind spots) in it visible Tools make the abstract concrete and therefore visible. Some mechanisms such as the Homepage or the Main Menu provide a visible summary of thinking (both analysis and synthesis) at a glance. The tool-based collaborative process makes thinking visible because thinking is externalised through social interaction and discourse.	1. Devise tasks that promote visibility of thinking including tasks that require strong visual components such as graphs, maps, video tasks 2. Provide multiple models of such tasks so that students can *see* what the final artefact might *look* like 3. Encourage students to *look* at their work from different *perspectives* using tool-based mechanisms that allow them to alternate between different design levels: summary- detail, overview-individual component (using features such as outlining, summaries subtotals, pivot tables etc) 4. use coaching to help students gain in*sights* into those aspects of their performance of which they are initially unaware, (blind spots); especially in*sights* into the collaborative and regulatory aspects of metacognition, especially planning and control **5.** Develop informal peer assessment criteria. For instance student showcase their artefacts. Peers are encouraged to look for and critique the thinking behind it

Tools can facilitate the natural acquisition of all Knowledge types (factual, conceptual, procedural)	The Core Tool structure Database Design – Datasheet order of task elements	In authentic tool-based tasks, knowledge factual, conceptual, procedural; general and domain specific is acquired in the natural context through its application to meaningful, authentic tasks Different phases of the tool-based tasks may require different types of knowledge. Knowledge is acquired at the natural time, in the natural order as the need arises. The tool enforces the order of the task elements The tool tacitly embodies the factual, conceptual and procedural knowledge - general and domain specific- central to the overall knowledge framework of the domain. The chart wizard, for instance, embodies - general and domain specific conceptual and procedural knowledge about graphs.(ref) Such tacit embodiment invites the student to internalise the knowledge as one's own knowledge framework	1. Devise meaningful, authentic tasks which promote the natural acquisition of knowledge – that is tasks which are central to the overall knowledge framework, course objectives and/or fundamental questions of the discipline 2. Design learning episodes that explicitly include an appropriate balance of factual, conceptual and procedural knowledge in their goals 3. Model the procedural (knowledge) aspects of critical thinking (know how) 4. Encourage exploration of resources relating to all knowledge types but especially factual and conceptual knowledge. 5. Align assessment to the key features of the knowledge framework that is being used on the course. Assess for understanding of the overall framework, fundamental assumptions, principles, concepts, interrelationships, questions and the application of the model.

Can facilitate Meaning-Making	All tool mechanisms	The tool facilitates meaning-making by the transformation of the abstract into the concrete The tool facilitates first hand experience, subjective knowing of what things *mean* and in so doing encourages individual perspectives on meaning Where students are unclear, however, about meaning, one way the tool exposes their misconceptions as incorrect assignments of the conceptual to the technical The tool has technical components, the task has conceptual components. Students are forced to be clear on the *meaning* of each of the conceptual components if they are to correctly assign each to their corresponding technical component.	1. Devise tasks that are *meaningful* – that is non-trivial tasks aligned to students' learning outcomes (as well as course objectives and frameworks) 2. Design tool-based tasks to yield first hand experience and knowledge. Such tasks might include: an examination of primary sources, conduct of one's own empirical 'research', building one's own knowledge base, writing a poem, building one's own website 3. Encourage multiple perspectives and meanings 4. Address misconceptions 5. Devise assessment instruments that can accommodate multiple meanings and embodiments of knowledge (essay, artefact, movie, story, concept maps etc)

Appendix 7.2: Two Examples of Alexander's Patterns: a Garden Seat and a Bed Alcove

176 GARDEN SEAT



Somewhere in every garden, there must be at least one spot, a quiet garden seat, in which a person - or two people - can reach into themselves and be in touch with nothing else but nature**.**

Throughout the patterns in this pattern language we have said, over and again, how very essential it is to give ourselves environments in which we can be in touch with the nature we have sprung from -see especially CITY COUNTRY FINGERS (3) and QUIET BACKS (59). But among all the various statements of this fact there is not one so far which puts this need right in our own houses, as close to us as fire and food.

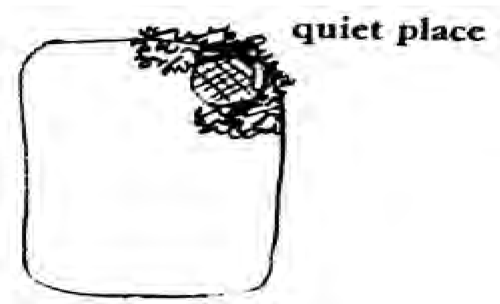
Wordsworth built his entire politics, as a poet, around the fact that tranquility in nature was a basic right to which everyone was entitled. He wanted to integrate the need for solitude-in-nature with city living. He imagined people literally stepping off busy streets and renewing themselves in private gardens every day. And now many of us have come to learn that without such a place life in a city is impossible. There is so much activity, days are so easily filled with jobs, family, friends, things to do that time alone is rare. And the more we live without the habit of stillness, the more we tie ourselves to this active life, the stranger and more disquieting the experience of stillness and solitude becomes: city people are notoriously busy-busy, and cannot be alone, without ‘input’, for a moment.

It is in this context that we propose the isolated garden seat: a place hidden in the garden where one or two people can sit alone, undisturbed, near growing things. It may be on a roof top, on the ground, perhaps even half-sunken in an embankment.

There are literally hundreds of old books about gardens which testify to this pattern. One is Hildegarde Hawthorne's The Lure of the Garden, New York: The Century Co., 1911. We quote from a passage describing the special kind of small talk that is drawn out of people by quiet garden seats:

> "Perhaps, of all the various forms of gossip overheard by the garden, the loveliest is that between a young and an old person who are friends. Real friendship between the generations is rare, but when it exists it is of the finest. That youth is fortunate who can pour his perplexities into the car of an older man or woman, and who knows a comradeship and an understanding exceeding in beauty the facile friendships created by like interests and common pursuits; and fortunate too the girl who is able to impart the emotions and ideas aroused in her by her early meetings with the world and life to sonic one old in experience but comprehendingly young in heart. Both of them will remember those hours long after the garden gate has closed behind their friend forever; as long, indeed, as they remember anything that went to the making of the best in them."

Make a quiet place in the garden - a private enclosure with a comfortable seat, thick planting, sun. Pick the place for the seat carefully; pick the place that will give you the most intense kind of solitude.



188 BED ALCOVE

….bed alcoves help to generate the form of BED CLUSTERS (143), COMMUNAL SLEEPING (186) and MARRIAGE BED (187). For children, each alcove also functions as A ROOM OF ONE'S OWN (141), so that even in the smallest house, not only the adults, but every child can have at least a small place to call his own.

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Bedrooms Make No Sense

The valuable space around the bed is good for nothing except access to the bed. And all the other functions – dressing, working, and storage of personal belongings which people stuff uncomfortably into the corners of their bedrooms – in fact, need their own space, and are not al all well met by the left over areas around the bed.

In BED CLUSTERS (143), we have already argued that each child in a family should have a bed alcove of his own, opening off a common play-space. This is based purely on the balance between community and privacy. We shall now try to establish the fact that, for everyone in the house, isolated beds, not only those in clusters, are better off in alcoves than in bedrooms. There are two reasons.

First, the bed in a bedroom creates awkward spaces around it: dressing, working, watching television, sitting, are all rather foreign to the side spaces left over around a bed. We have found that people have a hard time adapting the space around the bed to their needs for bedroom space.

Second, the bed itself seems more comfortable in a space that is adjusted to it. In our design experiments, where lay people have used these patterns to design their own houses, we have some kind of enclosure. Apparently this particular pattern strikes a chord in people.

Once the bed has been build into a space that is right for it, then the rest of the bedroom space is free to shape itself around the needs for sitting space, play areas, dressing, and storage.

What are the issues at stake in making a good bed alcove?

Spaciousness. Don't make it too tight. It must be comfortable to get in and out and to make the bed. If the alcove is going to function as A ROOM OF ONE'S OWN (141) for a child, then it needs to be almost a tiny room, with one wall missing.

Ventilation. Bed alcoves need fresh air; at least a vent of some kind that is adjustable, and better still a window.

Privacy. People will want to draw into the alcove and be private. The opening of the alcove needs a curtain or some other kind of enclosure.

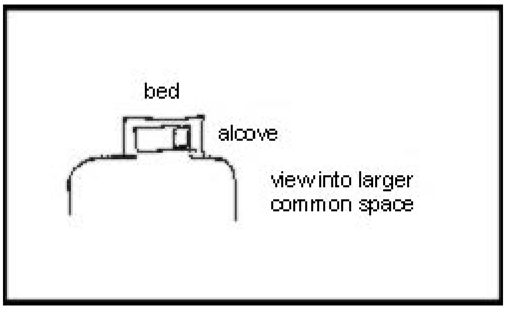
Ceiling. According to the arguments developed with the pattern CEILING HEIGHT VARIETY (190), the bed, as an intimate social space for one or two, needs a ceiling height somewhat lower than the room beside it.

Therefore:

Don't put single beds in empty rooms called bedrooms, but instead put individual bed alcoves off rooms with other non-sleeping functions, so the bed itself becomes a tiny private haven.

If you are building a very small house no more than 300 or 400 square feet – perhaps with the idea of adding to it gradually – this pattern plays an essential role. It will probably be best then to put the alcoves off the family room.

Build the ceiling low – CEILING HEIGHT VARIETY (190); add some storage in the walls around the alcove – THICK WALLS (197), OPEN SHELVES (200), and a window, in a natural position – NATURAL DOORS AND WINDOWS (221). Perhaps HALF-OPEN WALL (193) will help to give the alcove the right enclosure. Where space is very tight, combine the bed alcove with DRESSING ROOM (189). And finally, give each alcove, no matter how small, the characteristics of any indoor space – THE SHAPE OF INDOOR SPACE (191)…



Appendix 7.3: Sample Patterns

Critical Thinking Effect	**Cognitive: tools can facilitate the deepening of understanding**
Broad Precept	Design tasks that generally include higher order cognitive skills in their goals and more specifically, require depth of understanding.
Heading	**Depth of Understanding**
Key issue	When asked to consider the effect of a public policy initiative the critical thinker analyses the policy at levels of progressive depth. S/he may first consider its broad national implications. Next s/he might explore its consequences at a regional level, then its implications at city level. Finally, s/he might try to envisage in some detail the challenges of implementing that policy 'on the street'. This might be described as a deep approach to policy analysis. Knowledge that is deep demonstrates a clear understanding of the relationship of one idea to another, including cause and effect relationships. Research shows that students with depth of knowledge are much better able to apply their knowledge to contexts, 'beyond the classroom', such as the workplace. Frequently, however, it happens that students can recite 'the facts' but, when probed, do not really understand their deeper meaning. This lack of understanding might be manifested as an inability to relate these facts to other facts or an inability to apply them. Such understanding might be described as superficial. Depth of understanding is the opposite of superficial understanding.
Common Error	One does not achieve depth by adding *more*. For instance, when you add more by presenting students with large quantities of information, it often proves difficult for students to properly digest such information. This typically results in a very superficial understanding of the material.
General advice	Deep approaches to learning and depth of understanding can be facilitated by encouraging students to specialise in something that particularly interests them. If you can, encourage each student to become an expert in something, no matter how small. In addition to improving depth of understanding, this can also be highly motivating.
Tips/ Rule of Thumb	1. Here are some useful questions for encouraging deep approaches to learning and depth of understanding • Your description of the situation is interesting but what do you think are the reasons for what you describe

	• Do you think your view is related to any other view you have heard • What might be the direct opposite of that view • What do you think might happen if… 2. Get students to specialise in one small aspect of the course 3. Encourage students to showcase their specialist work
Tools	Tools are useful for deepening knowledge. Try this: get your students compose an electronic tutorial on some aspect of the learning program. This obliges students to list their ideas, order them and link them at progressive levels of depth by using hyperlinks. For instance, in a tutorial on motivation the Homepage may contain a general introduction to motivation, the next level might give a brief overview of some ‘schools of motivation’, the next level might focus on a theorist in a school and the next might describe a theory. Each level, representing a progressive deepening of knowledge, is linked to the next by hyperlinks. Click on the link to see this student-created tutorial on motivation.

Critical Thinking Effect	**Metacognitive: Tools Expose Weaknesses in Critical Thinking**
Broad Precept	Make students aware of the key concepts of metacognition
Heading	**Metacognition**
Key issue	Do you think the following statements have anything in common? • Patrick keeps making the same mistake • James has a very positive view of his performance, but is blind to his shortcomings • John writes good assignments but they are always late • When asked about an assignment he has just handed in, David has no idea whether it is good or bad • Mary has plenty of ideas but when given a topic to write on, she seldom plans it out, she more or less starts writing and keeps writing until she stops • Michael, a sociology student, believes that he will never be any good at statistics – because people, he believes, are ‘born either good or bad at maths’

	One common theme in each of the examples above is that each student has a problem with the way they think about their learning or the way they manage their learning. Metacognition, which has recently emerged as one of the key determinants of learning and critical thinking, can be thought of as the ability to (1) reflect on one's performance and (2) to regulate that performance. Metacognition is often described as 'learning to learn'. In general research shows that students' are largely unaware of what metacognition is, therefore their metacognitive capacities are underdeveloped. This means that students often underachieve not because they don't know 'things' but because they are not good at managing their learning.
Common Error	Getting students to reflect on their performance might be seen as a waste of time- time that could be spent acquiring new knowledge or tackling course-related problems. Yet sustained reflection and helping students to learn for themselves is key to improved performance.
General advice	When encouraging students to reflect on their performance it is helpful to explicitly direct their attention at three components: Task Strategy The Individual student (including/especially oneself). Thus in relation to any learning episode, such as an assignment or a chapter from a text or an article, the student might reflect on the difficulty of the task and/or the suitability of the end result, the appropriateness of the strategies used to approach the task and on the strengths and weaknesses of his own performance Regulation primarily involves the planning and control of learning. Making students conscious of planning and control – by perhaps requiring explicit evidence of these skills in assignment work- is an essential part of student learning and development. Consciously include metacognitive work in all your programs
Tips/ Rule of Thumb	Explain what Metacognition is - Just as you would with any topic on your course - and why it is important. Be as explicit as possible At regular intervals, (end of a class, end of a morning, end of a day) take a time out. Ask students to briefly (5 mins) write down what they

	have learned. Make this a regular feature so that students can get used to it. These observations can become part of a larger learning portfolio.
Tools	Do you find that writing something down clarifies your thinking? In a sense all tools, whether pen and paper or web-authoring tools support Metacognition because they make the thinking inside our heads external, they clarify it and make it available for reflection. A wide variety of tools can are useful for metacognition Some tools are particularly useful for reflection: • Online discussion tools and Blogs • Portfolios • Tools for collaborative work that provide peer feedback • Video & Showcasing tools Some tools are particularly useful for regulation: • Project mgt & planning tools • Calendars & Time mgt tools • Concept mapping • Outlining tools

Critical Thinking Effect	**Knowledge: Tools can facilitate the natural acquisition of knowledge**
Broad Precept	Design learning episodes that explicitly include an appropriate balance of factual, conceptual, procedural and metacognitive knowledge in their goals
Heading	**Balance Different Knowledge Types**
	Knowledge is essential for critical thinking. Here are examples of 'things' people know. What distinctions you would draw between them? S/he knows… the capital of Australia how to open a file in a spreadsheet the meaning of the concept of Rate of Return when s/he is having a problem 'Knowing the capital of Australia' is an example of factual knowledge. Many people, when they talk of knowledge, this is the kind of knowledge they have in mind. This kind of knowledge is associated with the ability to recall facts. 'Knowing how to open a file in a spreadsheet' is an example of a different kind of

	knowledge, procedural knowledge, which refers to the ability to carry out a procedure or follow a set of steps. 'Knowing the meaning of a concept' is an example of conceptual knowledge. This is used to describe the ability to understand interrelationships between ideas and concepts. The last example is referred to as metacognitive knowledge. This is the least well known knowledge type but is now considered to be an essential aspect of critical thinking. Metacognitive knowledge refers to the ability to reflect on strengths and weaknesses as well as to regulate their performance.
Common Error	Learning programs sometimes overemphasise factual knowledge at the expense of other knowledge types (REF). If assessment, also, focuses on factual knowledge, learners tend to respond with learn-by-rote strategies- the very opposite to what is required for critical thinking.
General advice	Consciously include all four knowledge types at program design stage, in a proportion that seems reasonable to you.
Tips/ Rule of Thumb	(Program Design) For each main topic on the program, a useful sequence, which covers most knowledge types, is: • Student(s) carry some procedure first e.g. create a database, role-play an interview a customer). • You help students understand the concepts that underlie the procedure. (conceptual) • Student(s) reflect on their performance (metacognitive) Here is a quick way to determine the knowledge balance in a program. Program Review • List the topics in the program. • In 30 seconds, indicate the main knowledge type beside each topic. • Review list and determine the dominant knowledge type being taught? If, for instance, factual knowledge predominates, then this may be an indication that the critical thinking content can be augmented by including more conceptual, procedural or metacognitive knowledge. If on the other hand the program is mostly conceptual, it might be useful to balance this with some procedural knowledge, such as using a spreadsheet, drawing up a survey etc.
Tools	Tool-based tasks are extremely useful for helping to develop all

	four knowledge types. For instance, in the case of a students using a spreadsheet to conduct a cost benefit analysis (CBA), the students must o review some *facts* about CBA before they can use the tool, o learn the *procedure* for applying these on a spreadsheet o learn the *concepts* that underlie procedure, o reflect on *metacognitive* feedback (e.g. an error message) that the tool provides