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**LEARNERS AS DESIGNERS:
COMPUTERS AS COGNITIVE TOOLS IN ARCHITECTURE
EDUCATION**

A thesis submitted in fulfillment of the requirements for the
award of the degree

DOCTOR OF PHILOSOPHY

from

UNIVERSITY OF WOLLONGONG

by



IAN HART, B.A., DIP.ED., M.ED.

**FACULTY OF EDUCATION
1996**

DECLARATION

Except where stated in the text, and in the list of acknowledgments, this thesis represents the original work of the author, and the material has not been submitted for a degree to any other university.

Final corrections have been made to the text in accordance with the examiners' reports.

Ian Hart

March, 1997

SUMMARY

In a problem-based, computer-intensive learning environment, what is the nature of the interaction between student characteristics, computers and cognition? The question is examined in the context of an intensive study of 19 students of Architecture undertaking a 6 month problem-based course in which they were required to work collaboratively on the design and construction of interactive 3D models using a range of software in a Silicon Graphics laboratory. The research method was predominantly naturalistic and data-driven, employing video observation, interviewing, mind mapping and mental modelling. The computer tool used to organize, search and report on the data was NUD•IST (Non-numeric Unstructured Data – Indexing, Searching & Theorizing). The research strongly supported the constructivist paradigm of learning and isolated a range of factors which are relevant to successful cognitive construction in computer-rich environments: approach to learning, as measured on the Study Process Questionnaire; declarative, procedural and contextual knowledge of computing; the ability to make connections between computing and domain concepts; metacognitive awareness, in particular the conscious use of distributed cognitions; and recognition of the “affordances” of the computer system. The highest achieving students exhibited an overall deep approach to learning (with above average scores on deep motive) and a high level of contextual computing knowledge and structural integration of domain and computing concepts. Follow-up interviews were conducted 6 and 12 months after the course and these provided some evidence of what Salomon (1993) describes as “cognitive residue” or long-term effects of working with intelligent tools.

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INTRODUCTION

This Ph.D. thesis began life in 1990 at the University of Canberra as an action research project on authentic video for Chinese language learning. My appointment to the University of Hong Kong in 1992 meant losing my pool of subjects (Australian secondary students) so rather than try to reproduce the study I decided to look for a topic more relevant to the educational concerns of my new environment. The subject matter of the present study – computers as cognitive tools in Architecture – may seem a far cry from the original, but the assumptions remain the same: the importance of individual differences, a predominantly constructivist view of learning, and a methodology based on “action research” and naturalistic forms of enquiry.

In the course of trying to reinvent my Ph.D. research in a Hong Kong context I investigated a number of educational multimedia projects then under development. The most promising of these was the Faculty of Architecture’s “interactive visual dictionary” of building structures, materials, regulations and methods being developed by John Bradford and his Ph.D. student Waycal Wong, using the university’s first Silicon Graphics work station. In 1993 the Architecture Department received a capital grant to install a complete laboratory of SGI machines. Barry Will, the Dean, and John Bradford proposed an experiment to introduce 3D computer modelling into the graduate program (Bradford, Ng, & Will, 1992a; Bradford, Ng, & Will, 1992b). As a first step Will included some computer modelling problems in his 1993-94 Building Systems class. The experiment received such positive feedback from students that in 1994-95 the problem-based approach to 3D computer modelling was formally incorporated into the curriculum.

As accreditation of professional programs is dependent upon the approval of the local industry and professional organizations, the

Architecture department was anxious to demonstrate that such a departure from traditional teaching methods was educationally effective. They were, therefore, happy to collaborate with me on a longitudinal study of the 1994-95 cohort of students. Together we made an application for funding from the University Research Grants Council to assist with documenting the progress of the course.

One of my aims was to continue and further develop the naturalistic methods of enquiry I had been pursuing in the earlier project, so rather than devise a “conventional” educational technology research design with a hypothesis and a control group, we adopted instead the Action Research paradigm. Action research is a cyclical process of acting – observing – reflecting, in which the learners are accepted as participants in the research rather than looked upon as subjects under investigation (Carr & Kemmis, 1986; Stringer, 1996); the antithesis of what Biggs (1995) has described as: “the whistle-clean, four-square symmetry of the psycho-lab.” (p.50)

The action research project provided an ideal setting for my own research on the role of computers in education, not as delivery vehicles for information (e.g. through CAI), but as cognitive tools with which students construct their own learning.

I posed the following question:

In a problem-based, computer-intensive learning environment, what is the nature of the interaction between student characteristics, computers and cognition?

Investigating the question involved observing the Building Systems class as they came to terms with working in a demanding, production-oriented computing environment over a period of 5 months (with follow-ups 6 and 12 months later). The methodology was qualitative and data-driven, utilizing a variety of research tools and an approach which owes a great deal to the “grounded theory” of Anselm Strauss (1987; 1990). The

aim of this project was not to produce a new theory nor to prove or disprove a hypothesis, even a null hypothesis, but to seek for what Guba (1982; 1988) and Richards (1993; 1992) see as the real goals of qualitative research: "perceptions", "insights" and "coherence".

1. **Chapter 1** situates the question within the context of historical and current research on learning and research methodology.
2. **Chapter 2** situates *the problem-based computer-intensive learning environment* within the narrower context of architectural education at the University of Hong Kong and describes the Building Systems curriculum and the computing facilities.
3. **Chapter 3** describes the heterogeneous and unstructured data which was collected over the 18 months of the study.
4. The classification of *student characteristics* is the subject of **Chapter 4** and includes both qualitative measures based on normed scales and a number of less conventional, qualitative indicators. The resulting individual student profiles have been compiled in **Appendix A**.
5. The students' *interactions* with computers and the Building Systems course are collected, classified and analyzed in **Chapter 5**, using the NUD•IST™ indexing system.
6. **Chapter 6** is a narrative treatment of the interaction derived from Chapter 5's indexing structure and consists of case studies of the four student projects. **Appendix B** contains off-line documents relating to the projects.
7. **Chapter 7** examines two types of *cognition*: which emerged from the data as particularly significant: metacognition and distributed cognitions.
8. Finally, **Chapter 8** returns to the original question and considers what the study has provided in terms of perceptions or insights into the

interaction of student characteristics, computers and cognition and suggests a hypothesis which can be tested using the data.

A journal article and a book chapter relating to my original research work on educational technology and language learning have been published (Hart, 1992; Hart, 1995b) and a number of refereed conference papers and reports have been produced as part of the Action Research Project (Bradford, Hart, & Will, 1995; Hart, 1995a; Hart, 1996; Will, 1995). Three of these papers are reprinted in **Appendix C**.

NAMES

Names can be a source of confusion for people unfamiliar with Hong Kong forms of address as most students have both a European Christian name and a three-syllable chinese name. In this thesis I have employed the names which the students prefer to be called by: e.g. Michael Yew Koon-wai prefers to be called Wai; Alice Teng Yiu-wai prefers Alice. Following is a reference list of the names which appear in this thesis.

Alice	<i>female</i>	Temple Base group
Bonita	<i>female</i>	Temple Dau-gung group
Christina	<i>female</i>	Curtain Wall group
Desmond	<i>male</i>	Temple Dau-gung group
Fai	<i>male</i>	Curtain Wall group
Frankie	<i>male</i>	Curtain Wall group
Han	<i>female</i>	Morphing group
Howard	<i>male</i>	Morphing group
Joan	<i>female</i>	Maintenance group
Leung	<i>male</i>	Temple Base group
Matchy	<i>male</i>	Ph.D. student (teaching assistant)
Mo	<i>male</i>	Maintenance group
Ronald	<i>male</i>	Temple Base group
Shirley	<i>female</i>	Maintenance group
Yat-man (aka Man)	<i>male</i>	Maintenance group
Yin (aka Ho-yin)	<i>male</i>	Temple Dau-gung group
William	<i>male</i>	Temple Base group
Wai (aka Michael)	<i>male</i>	Curtain Wall group
Wai-man	<i>female</i>	Morphing group
Wai-ling	<i>female</i>	Research Assistant
Waycal	<i>male</i>	Ph.D. student (teaching assistant)

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A number of individuals and departments provided generous assistance to me in the course of this project: the Department of Architecture at the University of Hong Kong, and in particular the Dean, Barry Will and Associate Professor John Bradford who manages the computer laboratory.

In December 1994 the Department of Architecture and Centre for Media Resources were awarded a 12 month grant under the Action Learning Project (funded by the University Grants Commission) to evaluate the introduction of computer-based teaching in the Architecture degree programme. The funds provided for the employment of a Research Assistant in the Architecture Department, Miss Yung Wai-ling. Her duties included assisting the lecturer with course organization, and documenting the progress of the course. She also assisted me with setting up and operating equipment, filing, translation from Cantonese to English and some preliminary indexing. Her assistance is gratefully acknowledged.

Twenty students contributed to this study and I would like to record my thanks to all of them for their generous and unreserved cooperation at all stages of the project.

Finally, I would like to thank Austra, my wife, for her consistent support over an unreasonable period; and Associate Professors John Hedberg and Barry Harper, my joint supervisors at the University of Wollongong, who went to extraordinary lengths (and locations) to provide feedback and encouragement.

Ian Hart

September, 1996

Chapter 1

Computers as Cognitive Tools

Summary: The style and scope of this chapter is, of necessity, somewhat discursive: it defines the research question and situates it within the context of a number of ongoing debates in the field of educational technology, in particular: (a) the effects of media on learning vs. media as a means of facilitating knowledge construction; (b) positivist vs. constructivist paradigms of cognition; (c) analytic vs. systemic approaches to research; and (c) internal vs. external validity. The concept of the cognitive tool is introduced, both in relationship to computers and learning and computer tools for research.

MEDIA AND LEARNING

For the past 30 years or more there has been an ongoing debate in educational technology journals over whether particular media are superior to others in promoting learning or whether particular qualities of media can assist in the development of certain types of knowledge. In part, the debate has been about the way in which the question was framed and the experimental methods which were employed to test the hypotheses.

Mielke (1968) in an article in *Educational Broadcasting Review* predicted that research on the learning benefits of various media would yield no significant difference between them. Schramm (1977), in a comprehensive meta-analysis of research in educational technology concluded that learning is influenced more by the content and instructional strategy than by the qualities of the medium. Lumsdaine (1963), Levie (1973) and Clark (1986) made the same points in the first three editions of the *Handbook of Research on Teaching*. But the debate did not gain real life until Clark's (1983) controversial article in the

Review of Educational Research where he claimed that on the evidence from 30 years of research, the media are "mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries changes our nutrition" (p.445). One suspects that the power of the analogy was on this occasion more provocative than Clark's argument which was, after all, simply bringing a 20 year old proposition up to date. Nevertheless, the media attribute debate has persisted into the 1990s, due in large part to the perceived cost-efficiency and learning benefits of computer assisted learning and multimedia (see, for example, Andrew (1995; 1991) Beaty (1990), Hart (1995b) Hawkrigde (1992)). In 1994 two issues of the AECT journal *Educational Technology Research and Development* were devoted to debating the issue again, with keynote articles by Clark (1994a; 1994b) and Kozma (1994a; 1994b) and contributions from a veritable arsenal of learning theorists and instructional designers.

From the perspective of this study, the most persuasive of the ETR&D articles was by Jonassen, Campbell and Davidson (1994), who attempted to refocus the debate with the proposal that we should not be concerned about the question of learning *from* media; a more productive field of enquiry is learning *with* media.

We believe that excessive effort has been expended for the past decade... arguing the wrong issue. We recommend restructuring the debate to focus not on the role of media as conveyors and deliverers of the designer's message to a stationary learner at the end of instruction, but rather on how media, however defined, can be used to facilitate knowledge-construction and meaning-making on the part of the learner. Questions about the role of media should focus on the effects of learners' cognitions with technology as opposed to the effects of technology. (p. 35)

The “with vs. of” argument refers to an article in *Educational Researcher* by Salomon, Perkins and Globerson (1991) which had posed the question:

People have been making machines more “intelligent.” Can machines make people more intelligent? More specifically, with the increasing use of intelligent computer programs, tools, and related technologies in education, it may be an opportune time to ask whether they have any effect on students’ intellectual performance and ability. (p.2)

The authors were not referring here to computer-aided instruction nor to artificial intelligence, but to systems which Pea (1987; 1993), Salomon (1993a), Resnick (1991) and others have called “distributed intelligence” or “distributed cognition.” While computer technology is at the heart of these systems, the principal relevance to this study is the interrelationship between the students, the technology and the learning activities which such “intelligent technologies” enable.

At university level, and particularly in professional courses such as architecture, accountancy, engineering and medicine, computers are increasingly seen as tools for performance enhancement which students will need to master as part of their professional competence. At the same time there has been a noticeable change in educational practice away from the conventional instructional formats such as lectures and tutorials towards problem-centred, collaborative approaches, on the assumption that such learning environments more closely reflect the needs of professional practice. (This is discussed further in Chapter 2.)

Are computers changing the ways in which students think about their subject matter, their learning goals or their approaches to study? Is exposure to “intelligent technologies” affecting the ways in which students think? This is the focus of the present study.

THE RESEARCH QUESTION

In a problem-based, computer-intensive learning environment, what is the nature of the interaction between student characteristics, computers and cognition?

This question requires definition:

PROBLEM-BASED LEARNING

Problem-based learning, first adopted widely in the health sciences, has also become a popular instructional method in other professional disciplines such as architecture and engineering. Barrows, one of the major contributors to the field of PBL, defined it as:

... the learning which results from the process of working towards the understanding of, or resolution of, a problem. (Barrows and Tamblyn, 1980)

The technique has now become so widespread at all levels of education that a Netscape search of World Wide Web sites (August 1996) using the phrase "problem based learning" returned over 180,000 hits. Finkle and Torp (1995), in an electronic article published on the web site of the Illinois Mathematics and Science Academy, provide the following definition: "problem-based learning is a curriculum development and instructional system that simultaneously develops both problem solving strategies and disciplinary knowledge bases and skills by placing students in the active role of problem solvers confronted with an ill-structured problem that mirrors real-world problems."

Boud and Feletti (1991), writing from the perspective of professional education, see PBL as a way of constructing and teaching courses using problems as the stimulus and focus for student activity. It is not simply the addition of problem-solving activities to otherwise discipline-centred curricula but a way of conceiving of the curriculum which is centred

around key problems in professional practice. "Problem-based courses move students towards the acquisition of knowledge through a staged sequence of problems." (p.14)

The traditional studio method of teaching in Architecture has many of the attributes of problem-based learning. Students learn to solve design and structural problems through intensive project work followed by presentation to peers and teachers. This is dealt with in more detail in Chapter 2.

COMPUTER-INTENSIVE ENVIRONMENT

Ellul (1964) divided technologies into two classes in terms of their afforded use: machines that work for us and tools with which we work. "The lever, the watch, and the automatic pilot work for us; the pencil, the hoe, the microscope, the camera, the slide rule require that we work with them; they do little without our active participation." (p.16) To this latter category, developed in the 60s, we could add the word processor, the CAD package and the data base. "Machines with which we work" are relevant to the learning environment proposed in this study, for these machines (unlike the ones that work for us) afford an "intellectual partnership in which results greatly depend on joint effort." (Salomon et al., 1991)

The computing environment in this study is not simply a facility to improve efficiency, such as a word-processing laboratory or library data base; nor is it a simulation laboratory of the type described by Lajoie and Derry (1993). The HKU Architecture Computer Laboratory is a tertiary version of the constructivist environments designed by Papert (1980; 1987) and Harel (1990) in which the computer is the medium both for cognitive construction and for presentation.

STUDENT CHARACTERISTICS

The most common matrix for the classification of students is based on intelligence quotient, whether it be measured according to the theories of

Binet, Thurstone, Thorndike or post-modernists such as Sternberg and Horn (Ackerman, Sternberg, and Glaser, 1989) or by Gardner's theory of multiple intelligences (Gardner and Hatch, 1989). Other ways of classifying students have been on the basis of abilities and preferred learning styles or on traits as diverse as field dependence/independence and left-right hemisphere dominance (Jonassen and Grabowski, 1993). However, by the time young adults reach university and have self-selected into courses, such classifications become all but meaningless in view of the fact that tertiary students have traditionally been viewed as an intellectual elite, expected to be able to adapt themselves to the requirements of their courses and the teaching styles of the staff.

Why then do students who are perceived to be of equivalent intelligence and background do better than others on certain learning tasks? In the 1970s, Marton and Säljö at the University of Gothenburg conducted a series of experiments on students' comprehension of text and proposed that many students' misconceptions were due to the fact that they processed the text at a different level to the one the writer intended. Marton chose the terms *surface* and *deep* initially to distinguish two levels of processing which involved contrasting focuses of attention: the surface level of the text itself and the deeper level of meaning which the author was trying to communicate. (Marton and Säljö, 1976)

From Marton's original work came the analytical description of learning in terms of *approaches to learning* and *outcome space*, and also a distinctive methodology, *phenomenography*, which showed how student learning could be investigated qualitatively, yet following a systematic and rigorous procedure. (Marton, 1986; 1988). Entwistle, Hounsell and Ramsden at the University of Lancaster further developed Marton's approach to contrast lecturers' and students' descriptions of teaching and learning, concentrating on the disparity between the motivations and study methods of students. (Marton, Hounsell, and Entwistle, 1984;

Ramsden, 1988) Out of this research came the concept of study orientation, implying that *approach* was to some extent a stable characteristic of the student, or at least that some students adopted consistent approaches across a range of different study tasks.

This view of the significance of students' approaches to learning, or predispositions to approach learning tasks in distinctive ways, proved a particularly fertile field for research in the 1980s. In Australia Biggs, working with the Australian Council for Educational Research, developed a predictive questionnaire (Biggs, 1987; Biggs, 1991) which has been adopted in this study to describe student approaches to learning. It will be discussed in more detail in Chapter 4. Other indications of student characteristics were developed over the course of the study and have been grouped at Appendix A: Student Profiles.

COGNITION

Cole (1990) distinguishes what she calls the quantitative and qualitative traditions in our educational thinking. Those with a quantitative outlook see learning as the aggregation of content: to be a good learner is to know more. The contents of learning are treated as discrete quanta or destructured units of declarative or of procedural knowledge, any one unit being functionally independent of any other. This is the common lay view of learning, where intelligence is equated with memory for facts. But it is also a view espoused by professional educators, particularly as Shepherd (1991) points out, by educational evaluators responsible for central curricula and external examinations.

Those with a qualitative outlook see meaning as the focus of a learning episode. Learning the meaning of an event, topic or phenomenon is a holistic activity. It is not achieved by learning piecemeal, however accurately, the units constituting the object of learning. Further, the learner acquires a progressively more complex

knowledge base, and as the knowledge base is used to construct meaning, meanings change with experience. Learner's comprehension of taught content is therefore "more like climbing a spiral staircase than dropping marbles into a bag, with qualitative changes taking place in the nature both of what is learned and how it is structured at each level in the spiral." (Biggs, 1995)

The family of teaching and learning theories based on qualitative assumptions is known as constructivism (Biggs, 1995; Duffy and Jonassen, 1992; Harel, 1990; Jonassen, 1991; Reeves, 1995) which is a perspective on learning emphasizing that: (i) knowledge is actively constructed by people for themselves, not absorbed from outside like a sponge absorbs water, and (ii) the frameworks used to construct and interpret knowledge come from social interaction, rather than direct instruction.

Constructivism has enjoyed a recent surge of popularity, but it is by no means a new theory. Bruner (1986) postulated that constructivism began with Kant, who in his *Critique of Pure Reason* argued for *a priori* knowledge that preceded all reasoning. It is what we know, and we map onto it *a posteriori* knowledge, which is what we perceive from our interactions with the environment. But what we know as individuals is what the mind produces. Kant believed in the external, physical world (noumena), but says that it is known only through our sensations (phenomena) — how the world appears to us.

From the viewpoint of constructivism, thinking is grounded in perception of physical and social experiences, which can only be comprehended by the mind. What the mind produces are mental models that explain to the knower what he or she has perceived. According to Kant, rather than being driven by external structures, these mental models are *a priori*.

The argument against constructivism is that in abandoning the idea of a unique, correct description of reality it makes science impossible. Not

so, wrote Lakoff (1987), it only gives up on scientific objectivism. The difference is important.

Scientific objectivism claims that there is only one fully correct way in which reality can correctly be divided up into objects, properties, and relations. Accordingly, the correct choice of objects is not a matter of a choice of conceptual schemes: there is only one correct way to understand reality in terms of objects and categories of objects. Scientific realism on the other hand, assumes that “the world is the way it is,” while acknowledging that there can be more than one scientifically correct way of understanding reality in terms of conceptual schemes with different objects and categories of objects. (p. 265)

The influence of thinkers such as Dewey, Piaget, Vygotsky and Bruner has been profound in reshaping our view of education as active engagement rather than passive reception of given knowledge. According to Laurillard (1993), although the promotion of active engagement with learning is increasingly evident in K-12 curricula, the idea of knowledge as an abstract Platonic form still lives on in many universities and has been given encouragement by information processing models of cognition “which use the metaphor of knowledge structures or conceptual structures in order to describe mentalistic entities that can be changed through instruction or even represented in a computer program.”(p.15).

By contrast, the view of cognition as *situated* stems from the Vygotskian view of the social character of learning (Vygotsky, 1978). The learner is seen as located in a certain situation and what is known from that experience is known in relation only to that context:

We should abandon once and for all any notion that a concept is some sort of abstract, self-contained substance. Instead, it may be more useful to consider conceptual knowledge as in some ways similar to a set of tools. (Brown, Collins, and Duguid, 1989 p.5)

COGNITIVE TOOLS

The metaphor of the cognitive tool is central to this study. Derry (1990) defines cognitive tools as both mental and computational devices that support, guide and extend the thinking processes of their users. Many cognitive tools such as cognitive and metacognitive learning strategies are internal to the learner; here, however, the tools we are dealing with are *external, computer-based environments that extend the thinking processes of the learners.*

There has been considerable debate in recent times between the advocates of intelligent tutoring systems (ITS), who assume that "students' thinking processes can be modelled, traced and corrected in the context of problem-solving, using computers." (Lajoie and Derry, 1993, p.1) and those opposed to artificial intelligence (AI) paradigms who believe that it is not possible to construct adequate cognitive models and, even if it were, it would not be cost-effective. "The non-modellers", as Lajoie terms them, believe that it is preferable to encourage students to learn to monitor their own learning and problem-solving performance through the use of well-designed computer tools.

In December 1995 David Jonassen and Gordon McCalla debated the two paradigms at the International Conference on Computers in Education in Singapore, Jonassen taking the position that "If AI is not dead yet, it deserves to be" (Jonassen, 1995). Other well-known advocates of this position have been Perkins (1986), who suggests that knowledge itself results from and is a design; Lehrer (1993) and Salomon (1993b) who

have been actively developing hypertext models to assist students develop writing skills; Teasley and Roschelle (1993; 1995), who have developed software to encourage the collaborative construction of problem-solving knowledge; and Harel and Papert (Harel, 1990) whose goal has been for students themselves to construct computer-based presentations about a topic which other students can use as a learning tool.

The model proposed by Harel and Papert, while it was based on work with much younger students, is the closest to the model employed in the present study: here post-graduate Architecture students are using a variety of off-the-shelf computer tools to construct presentations designed to communicate complex ideas to laymen and future undergraduates.

KNOWLEDGE

There are many ways of describing knowledge, from the philosophical (e.g. Peirce, 1931-58) to the psychological (e.g. Bruner, 1986). In this study we adopt the now conventional divisions into types of knowledge first proposed by Ryle (1949) as: declarative knowledge (knowing *that*); and procedural knowledge (knowing *how*); to which we add contextual knowledge (knowing *where, when* and *why*). (Tennyson, 1994) The three levels are defined more precisely in a matrix for the evaluation of computing knowledge in Chapter 4.

We also use the term *structural knowledge* in relation to the development of mental models. Preece (1976) described structural knowledge as the pattern of relationships among concepts in memory. Jonassen, Beisner and Yacci (1993) believe that structural knowledge also has a metacognitive quality: "the awareness and understanding of one's cognitive structure" (p. 4). For the purposes of this study, the primary distinction between contextual and structural knowledge is the method by which it is described: contextual knowledge was identified in the transcripts and indexed at a series of descriptive nodes in the data base;

whereas structural knowledge, being most commonly represented diagrammatically, was identified and described using concept mapping techniques. (The issue is taken up in more detail in Chapter 4.)

LEARNING

We view learning then, as a process of acquiring what Piaget termed “cognitive complexity” whereby the learner develops a mental structure made up of links between different types of knowledge (declarative, procedural, contextual, structural) as a prerequisite to cognitive construction, or the creation of new knowledge. (Piaget, 1987)

This constructivist view of learning is neatly summed up in two of Minsky’s (1986) pithy *Principles*:

Papert’s Principle: Some of the most crucial steps in mental growth are based not simply on acquiring new skills, but on acquiring new administrative ways to use what one already knows. (p.102)

This principle is particularly relevant to the development of knowledge structures as a child, but at the age of 24 (the average age of our subjects) there is already a considerable baggage of acquired knowledge and structure which needs to be overcome:

The Investment Principle: Our oldest ideas have unfair advantages over those that come later. The earlier we learn a skill, the more methods we can acquire for using it. Each new idea must then compete against the larger mass of skills the old ideas have accumulated. (p. 146)

We observe the Investment Principle at work in this study as students struggle to reconcile their acquired knowledge and skills in design with the novel demands of a computing environment.

INTERACTION

This pivotal concept returns us to the work of Gavriel Salomon whose book *The Interaction of Media, Cognition and Learning* (1979) represented a turning point in the ongoing debate about the role of media (in this case television) in education. He argued that, to the extent that a medium's symbol systems call on quantitatively and qualitatively different mental skills, knowledge-acquisition outcomes can be expected to vary respectively.

The paper by Salmon, Perkins and Globerson (1991) quoted earlier is a development of Salomon's original position, examining the question of whether computer-based intelligent tools can augment and extend human intelligence. The authors make a crucial distinction between the effects *with* and the effects *of* computer tools. Pea (1987) believes that working with an intelligent tool has effects on *what* students do, *how* well they do it and *when* it is done. Salmon referred to this aspect of the interaction as effects *with* the technology. But there may also be long-term changes in mastery of knowledge, skill or depth of understanding as a *consequence* of interaction with computers. The authors refer to this as the "attainment of cognitive residue" — an effect *of* the technology.

In the context of this study the distinction could be illustrated by a student learning to design a 3D model on a computer using a CAD program. If the student displays enhanced design and computational skills and improved ability to visualize a 3D object as a 2D plan it would be due to effects *with* the CAD program. If the student subsequently displays improved design and visualization skills when working without the benefit of a computer (because of internalization of procedures initially mediated by it) it would be an effect *of* the tool.

The primary focus of this study is the effects *with* computer tools. We will be observing, in Pea's terms "what students do, how well they do it and when it is done." We will not attempt to enter the educational

technology debate about the possible effects *of* computers. To even begin to answer this question a much more extensive, long-term study with a larger population would be required.

METHODOLOGY

We noted above a quantitative/qualitative dichotomy in theories of cognition (Cole, 1990). This dichotomy is carried over into the question of research methods: experimental vs. ethnographic; hypothesis vs. grounded theory; internal vs. external validity; laboratory vs. everyday.

QUANTITATIVE VS. QUALITATIVE RESEARCH

A review of educational research journals reveals that qualitative methods are becoming more common, particularly in classroom research. Seen often as the main source of creative ideas and the strongest method of constructing new theories, qualitative techniques are increasingly being recommended and relied on for both small and large projects. (e.g. Ackerman, 1989; Biggs, 1995)

One need only scratch the surface of the qualitative vs. quantitative debate to understand that the terms quantitative and “qualitative are in themselves misleading. They are commonly accepted terms for both the contrasting paradigms and the methods associated with them. However, the contrasting paradigms could employ either or both quantitative and qualitative methods. Adherents of the quantitative paradigm are more likely to use experimental and quasi-experimental tools, while qualitative researchers are more likely to employ more descriptive techniques. However, focusing on methods is like focusing on the symptoms rather than on the cause of the disease. “Methods are manifestations of a manifold religion we call science” (Fetterman, 1988 p.5).

The fundamental difference between these two scholarly positions is based on philosophical and epistemological, not methodological,

grounds. The contrast, as we have observed in the earlier discussion of cognition, centers on the philosophical positions of positivism/objectivism and phenomenology. Typically, positivists search for social facts apart from the subjective perceptions of individuals. In contrast, phenomenologically oriented researchers seek to understand human behaviour from the insider's perspective. Their most significant reality or set of realities is found in the subjective realities of human perception. Essentially, a phenomenologically oriented researcher argues that what people believe to be true is more important than any objective reality; "people act on what they believe. Moreover, there are real consequences to their actions" (Fetterman, 1988, p.6)

LABORATORY OR LIFE?

An example of this controversy is the ongoing debate in the field of memory research which stemmed from a chapter by Neisser (1978) in *Practical Aspects of Memory* about the validity and scientific merits of laboratory vs. real-life research. A precursor to the educational technology debate provoked by Clark (1983), Neisser had attacked the laboratory approach that emphasizes internal validity over external validity, charging that nothing interesting or important had resulted from roughly 100 years of effort in the laboratory. Ten years later, Banaji and Crowder (1989) were still arguing that "the more complex a phenomenon, the greater need to study it under controlled conditions, and the less it ought to be studied in its natural complexity" (p.1192)

Banaji and Crowder's (1989) position assumes that the phenomenon studied under tightly controlled conditions is the same as the one encountered in real-life circumstances. As Conway (1991) pointed out in reply, laboratory-based study of episodic memory, although ostensibly examining the phenomenon of autobiographical memory, is in fact a study of something quite different: "Everyday autobiographical memory deals with memory infused with prior knowledge and personal

meanings, which the memory-in-the-lab tries to *control for*." (p.21)

Changing the context in which a phenomenon is studied may reveal a qualitatively different phenomenon, (Ceci and Bronfenbrenner, 1991).

ANALYTIC RESEARCH

Educational researchers have often attempted to apply the disciplines of the laboratory to classroom research. Salomon (1991) characterizes this laboratory approach to research as *analytic*. The goal of analytic research is to manipulate and control situations so as to increase internal validity and isolate specific causal mechanisms and processes. This has typically been done by conducting experimental studies of the sort reviewed by Clark (1983; 1989; 1994a) in which an independent variable is isolated by the experimental design and its effect on a dependent variable is measured. According to Kozma (1994b) this is similar to examining the effects of a tornado by taking photographs before and after the event. The photographs enable us to assess the extent of the damage but not the process by which the damage was wrought.

Classroom research presents the same dilemma. For Schon (1987 p.3) education is a "soft, slimy swamp of real-life problems" and the principles that guide learning in that eco-system are surely going to be different from those describing the course of learning in the whistle-clean, four-square symmetry of the psycho-lab (Biggs, 1995, p.50).

Reeves (1990) is in agreement, maintaining that small-scale studies, employing small sample sizes, few variables, laboratory settings, and short time frames fail to reflect the complexity involved in practical learning contexts and hence have severely limited generalizability. He has gone so far as to label such research "pseudoscience", but reports that in spite of overwhelming evidence of the flaws in controlled laboratory studies, it still continues, is regularly reported in academic journals such as *ETR&D*

and the now-defunct *JCBI* and is in turn cited by authors in a cycle of self-serving support (Reeves, 1993).

SYSTEMIC RESEARCH

Salomon (1991) proposed as an alternative a *systemic* approach to research design. The systemic approach is based on the assumption that “each event, component, or action in the classroom has the potential of affecting the classroom as a whole”(p.15). These variables act on one-another in interdependent ways. Changing one variable may have “dramatic and unanticipated effects as it propagates through the complex web of relationships among variables in the system” (ibid). As far as research methodology is concerned, Neuman (1989) proposed that ethnographic or naturalistic methods can effectively be used to identify and analyze the whys, hows and interrelationships of various instructional dimensions as they emerge in classroom activity. Long-term observation, interviews and artifact analysis provide a richness of detail about the social processes within which cognition is embedded. Such details are often missing from quantitative data.

DATA-DRIVEN RESEARCH

Much of today’s social science and educational research is characterised by methods designed to explore, find patterns, learn from a series of group discussions or an event. Researchers start from unorganised data and proceed to the formulation of an overall organising account of that data. This is termed data-driven research. Data-driven research may be susceptible to ideologically standard hypothetico-deductive testing of its conclusions, even if not in a formalisable way e.g. using statistics. But often, such testing is not meaningful, or else may not be particularly important, because it is the procedures of arriving at those conclusions that certify their validity.

In such research, the goals are perceptions, insights and coherence, rather than testing of hypotheses and theories (Guba and Lincoln, 1982; 1988). Using techniques of field research, group or individual unstructured interviewing, for example, the researcher may be seeking the unquestioned, often unformulated, assumptions that drive certain aspects of learning behaviour. In such cases the interviewer cannot question the respondents directly about their beliefs, because to the respondent they are unrecognised or unquestioned, non-issues. "Too close to be within arm's reach" as Ryle (1949) has said. The process of finding those beliefs involves sensitive qualitative analysis of the data, and the process of showing how those beliefs drive behaviour involves creative story-telling.

The test of the ultimate conclusion is ... to see how elegantly and methodically the evidence was shaped into the conclusion, how the conclusion was coaxed (never forced) to "emerge" from the data, how evidence and grand account form a well-connected, seamless web of belief that illuminates and enriches our perceptions and understanding of phenomena we see every day. To be credible, the report must show these processes in action, and demonstrate how the conclusions were reached. (Richards and Richards, 1992)

It is not within the scope of this thesis to provide philosophical justification of this sort of methodology of creation of explanations and theories. There are many texts that describe versions of this methodology in detail, e.g. Strauss (1987; 1990) Hammersly (1983) Burgess (1984) and which discuss the justifications of the methodology used, e.g. Atkinson (1990). The point to note here is that data-driven research is widely practised in many fields, including educational research, is essential to many research problems, and is not hypothesis-driven.

COMPUTING AND QUALITATIVE RESEARCH

In the past, manual methods of handling qualitative data tended to stress creativity and ignore or even reject demands for reliable procedures of data processing, testing and validation of results. In recent years, a revolution in qualitative computing has reversed this emphasis, and as computers become accepted, even required in qualitative research, there has perhaps been a tendency to put rigour before creativity. (Richards, 1995)

How can computers assist the researcher to preserve creativity while improving the degree of rigour? First, it is plain they cannot do it by themselves. The idea that you could feed unstructured, often scrappy text in at one end, and print out at the other a detailed, carefully argued and annotated theory of the learning behaviour of a community, is a preposterous (though often wished for) position. It should also be noted that it is not sufficient simply to aim to produce a theory, because in qualitative data analysis, what is needed for validation of the theory is the whole story on how the theory was derived.

The role of the computer, then, should be to support and enhance the creativity of the researcher.

Research by Richards (1991) into methods used by qualitative researchers suggested that support for creativity and rigorous analysis could be "best provided by allowing the researcher to create on the computer a structured indexing system that manipulates (an array) of concepts linked to the documentary data." (p. 93) The result was NUD•IST (Non-numerical Unstructured Data Indexing, Searching and Theory-building), a software package originally developed at La Trobe University and now in use in a range of research areas around the world¹. NUD•IST

¹ NUD•IST is copyrighted by Qualitative Solutions & Research Pty. Ltd. and is distributed internationally by Sage Publications, 6 Bonhill St, London EC2A 4PU, UK.

assists the researcher with the clerical stages of the project: recording, storage and coding; as well as the analytical work: data exploration, memo writing, data retrieval and the creative building of theory.

NUD•IST served as the primary cognitive tool used to structure this project.

VALIDITY

A source of discord between proponents of laboratory and ecological research has been the issues of generalization, ecological and functional validity. Banaji and Crowder (1989) argued that ecological validity of the methods is unimportant and can work against generalization of findings. They presented a sample of cases which demonstrate that low ecological validity of methods and high generalization of results is preferable to high ecological validity and low generalization. It can be argued, however, that the ecological nature of the situation is really of little effect or consequence as long as some basic principles of cognition can be discovered and those discoveries have a degree of external validity.

One way of handling the question of generalizability suggested by Guba and Lincoln (1988) is to bring certain criteria to bear on results: criteria such as credibility, transferability, dependability and confirmability, which are parallel to the conventional criteria of internal validity, external validity, reliability, and objectivity. They also propose additional authentication criteria:

1. Fairness, the process of identifying, presenting, clarifying, and honouring in a balanced way the multiple constructions and value positions that are bound to exist in a given context;
 2. Ontological authentication, determined by whether there is "improvement in the individual's and group's conscious
-

experiencing of the world” judged by whether persons achieve a more sophisticated or enriched appreciation of the context;

3. Educative authentication, whereby participants achieve increased understanding of the constructions that surround them;
4. Catalytic authentication, which is the facilitation and stimulation of action;
5. Tactical authenticity, the ability to act towards change, and to be empowered politically and educationally. (p.111)

TRIANGULATION

Another commonly accepted means of providing validity in evaluative studies is through the technique of triangulation, or the search for convergence across methodologies (Reeves and Okey, 1996). The assumption behind this approach is that different methodologies have compensatory strengths and weaknesses. Where several methodologies lead to the same conclusion, the researcher’s confidence in the conclusion is increased substantially. While triangulation is widely used as a technique for adding validity to qualitative research, for several reasons it must be treated more as a guideline than as a firm set of procedures. As Cronbach (1980) points out: first, it is difficult to know when two methods in fact present confirmatory evidence; second, when the evidence from different methods conflicts, it is difficult to know which method, if any, is more correct. That is, it is hard to assess the relative validity of data from different sources. On the other hand, seemingly contradictory evidence generated from different methods can all be correct, but represent different perspectives on or aspects of phenomena. Of course these problems often occur in harder, quantitative studies as well.

This study employed a variety of tools to gather and interpret the data. It therefore includes a degree of inbuilt triangulation. However the primary conceptual tool and organizing structure was the NUD•IST tree

and the following chapters rely on this indexing system to provide the form of validity proposed by Richards (above) to “tell the whole story on how the theory was derived.”

CONCLUSION

The research question concerns the ways in which individual differences in prior knowledge, skills and approaches to learning might affect the interaction with computer-based cognitive tools and the construction of meaning. In this chapter we have attempted to situate the question within current theories of cognition and movements in curriculum design which are gaining popularity in tertiary education, e.g.: the problem-based approach to curriculum, the employment of computers as cognitive tools for both learning and presentation, and constructivist, student-centred approaches to assessment. We have also described a qualitative, data-driven approach which could be employed to research the ways in which students interact with a computer-intensive environment in constructing new knowledge.

Chapter 2

Context Of The Study

Summary: This chapter situates the research question within professional education in general and architecture in particular. It describes the ways in which traditional, “apprentice” models of teaching architecture are evolving in the light of advances in technology and recent theories of teaching and learning. It then describes the curriculum of the Building Systems course and the computing environment within which the students worked.

ARCHITECTURE EDUCATION

In common with many schools of architecture, the University of Hong Kong provides a three-year undergraduate program (Bachelor of Science in Architecture) followed by a two year professional degree (Master of Architecture). The two are normally separated by a year of work experience in a commercial architectural firm.

The subject of this study is a class of 20 fourth year students. The study covers the second half of an elective unit called Building Systems, where the students were engaged in a series of intensive 3D computer modelling projects. It was the first time that any of them had been involved in this type of project and for some, it was the first time they had used any software more sophisticated than a word processor.

“TOWN VS. GOWN”¹

There is traditionally a degree of tension between the demands of the profession for graduates with technical and problem-solving skills and the views of academic staff who argue in favour of content and the encouragement of creativity and divergent thinking. Practicing

¹ In the British tradition, an annual cricket or football match between the university and the local population.

architects stress the importance of practical and interpersonal skills and positive work attitude. (Bilello, 1991; Hansen, 1991; Kennedy, 1989). Will (1995) argues that the considerable creative demands of an architecture course must be backed up by an understanding of science, mathematics and engineering. Elhanini (1986) and Rudd (1989) insist that in order to design buildings which meet community needs, architects require a knowledge of sociology, psychology, philosophy and education as well as a wide general knowledge of their culture and environment. A number of follow-up studies of architecture graduates have indicated the importance of both academic and practical aspects of professional training. In a study by Yohanan (1992) of a 1981 cohort ten years on, respondents rated the university's maths, psychology and specific architectural technology courses as most beneficial to them in their subsequent careers. Longitudinal studies by Domer (1983) in the USA and Philip (1990) in Australia found that satisfaction with the apprenticeship components of the course was significantly higher than satisfaction with the academic components.

TEACHING METHODS

The traditional and most established teaching method in architecture has been centred around the apprenticeship model of the "studio" where groups of students are assigned to a studio teacher called a critic who oversees their work and conducts regular "desk crits". In both the undergraduate degree and the Master of Architecture at the University of Hong Kong, "Design Studio" occupies half of the students' time and comprises 60% of their assessment. This close and ongoing contact between student and assessor has long been a subject of debate in architecture education. Dinham (1988; 1989), Janesick (1982) and Turyan (1983) all argue that in addition to the traditional benefits of the mentor relationship, there is a concern that assessment can be unduly influenced by personality factors and other issues falling outside performance criteria. Nevertheless, the consensus of opinion appears

to be that the studio method promotes both self-critical attitudes and high standards of work. (Dinham, 1989)

Unlike university disciplines which are based on a body of written text and can be taught by lectures and tutorials, architecture is multi-disciplinary and performance-oriented. Designing imaginative but viable structures demands that students can comprehend and manipulate abstract concepts, processes, visual images and physical objects, which means that teaching and learning rely heavily on 2D images, 3D models and moving pictures. In addition, the nature of design problems requires students to develop heuristic reasoning processes based on gradually acquired sets of rules, inferences and strategies (Rowe, 1982). These requirements place considerable demands on curriculum designers in architecture.

In recent times (and very much so in Hong Kong) the traditionally generalist nature of the architectural curriculum has come under pressure as the scope and extent of the separate disciplines of structures, services, construction materials, architectural history, and environmental studies have expanded exponentially in scale and complexity (see for example Brown (1987) and Kauppinen (1989)). Added to this has been the revolutionary impact of computing on all aspects of the architecture discipline.

The project described in this thesis represents an attempt to develop a teaching strategy which responds to these changing conditions while reconciling the academic vs. professional tension and explores and tests the potential of high-end workstations as an interactive teaching medium. The teaching staff involved see it as the precursor of a major change in professional educational methodology for architecture education (Bradford, 1995; Bradford, Ng, & Will, 1992b; Will, Bradford, & Ng, 1992; Will, Bradford, & Ng, 1993).

THE “BUILDING SYSTEMS” COURSE

Building Systems is offered as an elective unit in the first year of the Master's degree in Architecture. It is a unit in which students study the various systems which produce the built environment, e.g. structure, building skins, air conditioning, plumbing, etc. and comparisons are also made with other systems such as the aerospace, automotive and shipbuilding industries. The course introduces students to advanced and futuristic concepts, while at the same time analyzing traditional methods. The lecturer in charge of the course is Barry Will.

BARRY WILL: The general concept of the course that we want students to appreciate is that buildings don't just happen. They're organized systems. And although the building industry is a relatively disorganized industry, in comparison to the aeronautics industry which is very organized, the building industry still has its own sub-systems that make things work.

The first semester of the course is taught using a mix of lectures and drawing assignments, with teaching staff taking the lead and establishing the teaching paradigm. Roles are reversed in the second half of the year — students become the active leaders and staff take the roles of advisors and critics. This section of the course is totally computer-based and is the subject of this paper.

OBJECTIVES & IMPLEMENTATION

The following (Will, Bradford, & Hart, 1994) is an excerpt from the application for the Action Learning Project grant , which is an “official” description of the course objectives and proposed implementation:

Objectives

1. To make a direct comparison between conventional and computer based teaching methodologies
2. To optimize the available time to cover as many aspects of Building Systems as possible
3. To increase students' depth of understanding of the systems

4. To apportion work to different groups so that parallel programmes can be achieved
5. To make a comparison of the difficulties encountered by stand-alone groups compared with groups working on related projects
6. To explore the effectiveness of peer teaching and group interaction
7. To evaluate the effectiveness of the interactive multimedia, hypermedia, virtual reality and digital virtual design studio

Implementation

In the 1994-95 academic year, four projects will be put forward for students to work on:

1. An interactive multimedia model of a Tang Dynasty Temple
2. A multimedia presentation of morphing of structure
3. A multimedia presentation of the erection of a curtain wall system for a high-rise building
4. A multimedia presentation of an interactive programme for building maintenance for a high-rise building.

Topics 3 and 4 are directed towards the same building and the two projects are to be hyper-linked. Data for topics 1, 2 & 3 has been supplied by outside sources.

A number of interactive multimedia projects already exist, developed by staff and students in previous years of the Building Systems course. The most complex and complete of these is Temple Tutor – a set of interactive multimedia models of traditional Chinese temples (Bradford & Will, 1992).

Students will be required to proceed from pen and paper storyboards to 3D computer models produced at SGI workstations. This will be done as group work and the progress of each project monitored in weekly presentation sessions with the models presented on a CRT projector for analysis by the entire class.

THE COMPUTING ENVIRONMENT

MULTIMEDIA & HYPERMEDIA

Multimedia deals with the creation, storage and presentation of information in various media forms via computer. Hypermedia provides a hypertext style of interactive access to multimedia information. Existing multimedia and hypermedia systems in education, entertainment and information designed to run on PC platforms typically only support text, audio, images and animations and have comparatively low screen resolutions, limited display colours and slow graphic processing power. They lack the ability to present the complex line drawings and 3D models which are essential for architectural modelling work. (Bradford, Ng, & Will, 1992a; Bradford et al., 1992b)

THE MULTIMEDIA LAB

The Department of Architecture's multimedia laboratory incorporates a network of fast Silicon Graphics workstations together with a variety of input, output and display devices which include video, flatbed and slide scanners, b&w and colour printers and a 3-tube CRT projector for display of both computer output and video. (See *Appendix B* for a plan of the layout)

DEFINITIONS

The following definitions of computing terms used in the multimedia laboratory are included here as a background to technical discussions which develop later in the study.

File formats: The system uses digital ASCII text, audio, images, drawings, videos, animations and 3D models. Examples of supported formats and software are set out in Table 2-1.

SUPPORTED FILE FORMAT	SAMPLE SOFTWARE
TEXT: ASCII, BIG5 Code	ETEN, MS Word for Chinese Windows
IMAGE: RGB (SGI), TIFF, TARGA, GIF, JPEG	Photoshop, Photostyler, Imageworks
2D DRAWING: IV (Inventor) DXF	AutoCAD
3D MODELS: IV (Inventor) DXF	AutoCAD, 3D Studio
AUDIO: AIFF, AIFC	Sound Editor
ANIMATION: MV (Movie file format), Quicktime, MPEG	Makemovie, Movie Maker, 3D Studio (Keyframer) Wavefront (TAV Advanced Visualizer, Dynamation)

Table 2-1: File formats and software



Figure 2-1: Page from Temple Tutor

Text, audio & images: The standard multimedia elements of *text*, *audio* and *bitmap images* are available, and delivery is via a separate X-Window viewer for each medium. Figure 2-1 shows a 3D temple model with a bilingual TextViewer window and the AudioPlayer control panel. Highlighted Chinese characters in the TextViewer indicate hyper-links to additional information about the topic represented by the character. Links could be to further text or images, or to a spoken commentary or music presented via the AudioPlayer.

Drawings: Any computer-based system for architectural education must include provision for *drawing*. A line *drawing*

may appear to be similar to an *image* as both are displayed on the screen as flat 2D graphic elements. The difference is that an *image* is a bitmap which defines the colours of specific pixels, while a *drawing* consists of definitions of "vertices" and "vectors" which translate into pixels only when the drawing is displayed. This means that drawings can be accurately resized and the individual vectors can be selected as components for hyper-links.

Movies: Because all data is digital, computer generated *animations* and *videos* are exactly the same and are known as "movies". The term should not be confused with the cinematic linear format which runs at a fixed rate of 24 fps (25 or 30 fps in video). In multimedia a *movie* is a predetermined sequence of independent images (with or without associated *audio* track) displayed at a definable size and frame rate.

Models: Architecture students are taught to design 3D objects and spaces which are often too complex to understand when transformed into 2D drawings. Current CAD systems can model geometry, light, colour, transparency and texture, but commercially available multimedia systems can't use these models. The system developed at the University of Hong Kong uses interactive 3D models as another media element, and individual components within the model can be hyper-linked to adjunct information — including other 3D models.

This, then, is the context in which the study took place. A schematic diagram of the laboratory is provided in Appendix B, together with storyboards and sketches from the student projects.

CONCLUSIONS

The first two chapters have situated the study both within the wider context of theories of tertiary teaching, learning and curriculum, and within the particular context of learning architecture at the University

of Hong Kong. Chapter 2 has described the very sophisticated computing environment within which the project operated and has introduced the four projects which formed the core of the study. These will be described in detail in Chapter 6.

Chapter 3

The Data

Summary: The time scale of the study was 18 months, comprising an intensive 4 month period while students were working on the BS1 projects and several follow-up interviews to provide students with the opportunity to take a longer-term perspective on their experiences. This chapter describes the process of data collection, the procedures which were followed and the various types of data which were collected. The data include questionnaires, observations, transcripts of audio and videotapes, mental models and concept maps drawn by students, semantic networks produced by the computer from a semantic comparison test and off-line material collected in the course of the study.

TIMETABLE

The major part of the study took place over a four month period in the second semester of the Building Systems unit: between January and May of 1995. Two follow-up interviews were conducted: one in January 1996 with eleven of the original students who continued with Building Systems II in their second year, and the last in May 1996 when students had completed all requirements for the M.Arch. course, but before they were aware of their results.

A variety of data were collected over the course of the study: videotapes, audiotapes, written observations, questionnaires, mind-maps and semantic networks, sketches, storyboards and photographs. About 50% of the spoken material recorded was in English, the rest (several demonstrations and group discussions) was in Cantonese and was translated into English. The timetable of data collection is set out in Table 3-1 and Table 3-2.

- **On-line:** refers to text-based data in a form suitable for use in the NUD•IST data base;
- **Off-line:** refers to other data such as videotapes, storyboards and concept maps which must be physically stored and catalogued;
- **Text units:** refers to the number of 60 character lines of text in the transcribed interviews and relates to the way in which the NUD•IST program deals with data. The figures are included here merely as an indication of the relative amount of data collected from each exercise. This issue is dealt with more fully in Chapter 5.

ON-LINE

Date	Data Collected	Text Units
14 Jan 1995	Class observation#1 - video and notes	384
16-19 Jan 1995	Interview#1 - 3D modelling (18 students) Staff interviews: Barry, Waycal	3,158 673
10 Feb 1995	Class observation#2 - video and notes	117
24 Feb	Class observation#3 - video and notes	81
27 Feb-2 Mar 1995	Interview #2 - work-in-progress (18 students)	3,158
17 Mar 1995	Class observation#4 - video and notes	58
20-24 Mar 1995	Interview#3 - work in progress (15 students)	3,661
7 Apr 1995	Class observation#5 - video and notes	75
21 Apr 1995	Class observation#6 - notes	35
25 Apr 1995	Interview#4 - groups (17 students) Staff interviews: Matchy and Raymond	2,983 845
3-4 May 1995	Interview#5 - project demonstrations (8 students)	498
10-12 Jan 1996	Interview#6 - BS2 students (11 students)	1,696
15 May 1996	Interview#7 - final interview (17 students)	3,272
	Total text units	17,422

Table 3-1: Timetable of on-line data collection

OFF-LINE

Date	Data Collected
14 Jan 1995	Study Process Questionnaire (18 completed questionnaires) Class observation#1 (videotape)
16-19 Jan 1995	Interview#1 - 3D modelling (18 videotapes) Storyboards (from four groups)
10 Feb 1995	Re-administer SPQ (18 completed questionnaires) Class observation#2 (videotape)
24 Feb	Class observation#3 (videotape) Storyboards (total = 8, including revisions)
27 Feb-2 Mar 1995	Interview #2 - work-in-progress (11 videotapes) Mental model of server system (18 drawings)
17 Mar 1995	Class observation#4 (videotapes) Revised storyboards (from three groups) Project screen captures for WWW pages.
20-24 Mar 1995	Interview#3 - work in progress (12 videotapes)
7 Apr 1995	Class observation#5 (videotapes)
3-4 May 1995	Interview#5 - project demonstrations (4 videotapes)
15 May 1996	PFnet - concept maps from KNOT (17 students)

Table 3-2: Timetable of off-line data collection

SOURCES OF DATA

VIDEO OBSERVATION

Class meetings and project demonstrations were covered on videotape using a Sony Video 8 Handicam with 12x zoom lens and built-in and extension microphones. Two types of set-up were used: *hand-held* and *fixed p-in-p*.

Hand-held camera

Student teams were videotaped on several occasions as they worked on their projects in the computer laboratory and presented their work-in-progress at weekly classes using the CRT projector. The computer laboratory was not an ideal location for videotaping as it is a narrow room with windows along one side, harsh fluorescent lighting, a great deal of reverberation and very loud air-conditioning. This meant that the angle of

filming was restricted to one side and the camera needed to be very close to the speaker in order to be able to capture dialogue. The image filmed from the SGI screens flickered due to the difference between the screen refresh rate and 25 fps PAL video, making it difficult to distinguish detail. During classes when the curtains were drawn and the CRT projector was used, flickering was reduced, but the lighting levels were extremely low and it was difficult to distinguish students and teachers. The speakers' voices were also inaudible unless the camera happened to be at less than one metre distance.

Using the hand-held setup, therefore, did not prove to be productive. After the first attempt, it was decided that the Research Assistant would make a videotape record of screens and faces in order to provide reinforcement for notes taken by hand. After the session the notes of the meeting were written up, with the video tape serving as an *aide memoire*. These records appear as Meeting#1 through Meeting#6 in the data list.

Fixed camera with *p-in-p*

The most satisfactory image quality was obtained by recording directly from the SGI computer through a video converter onto the Handicam and combining this signal with the image from a fixed camera using a locally-manufactured picture-in-picture device. The connection diagram is illustrated in Figure 3-1.

The *p-in-p* system was adjusted so that the computer screen comprised the main image and an image of the student was superimposed in one of the four corners. Figure 3-2 shows the student's image positioned at the lower right of the frame as this is normally the least used area of the screen in graphic work. The sound problem was solved by using individual lapel microphones and a small audio mixer.

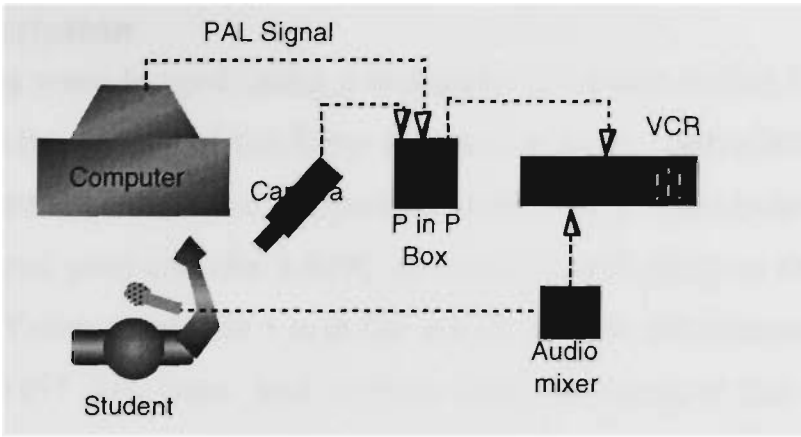


Figure 3-1: Connection diagram for video observation system

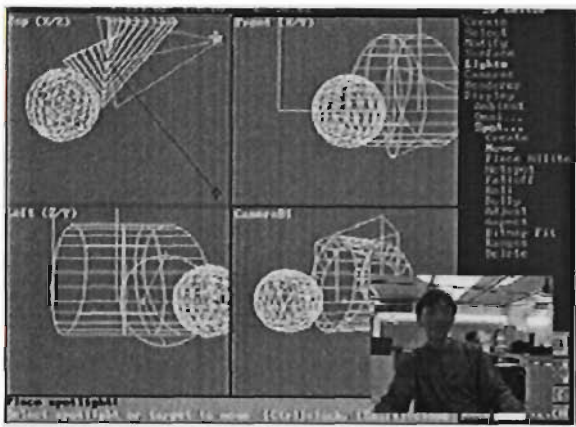


Figure 3-2: Output of p-in-p device

There was an early setback when it was discovered that the built-in video output from the SGI computer only provided a resolution of 640x480 pixels, whereas students were working with the full area of a 1280x1024 pixel high-resolution screen. This was solved once a Silicon Graphics Galileo video converter had been installed capable of delivering full-screen high-resolution video with a choice between RGB (broadcast quality), component (semi-professional), or composite output.

Video transcription

The videotapes were logged using a computer program called C-Video¹, which enables the replay of the Sony Handicam to be controlled directly from the Macintosh numerical keypad by means of a cable between the computer's serial port and the LANC remote control plug on the Handicam. C-Video produces a text file which can be introduced directly into the NUD•IST data base, and enables time stamping of the transcript.

Figure 3-3 illustrates the C-Video transcription format and includes two time stamps (underlining added).

```
TAPE START: 00:46:54
MO IS DEMONSTRATING THE "MAINTENANCE" PROJECT.
OPENING SPLASH SCREEN. DISSOLVES INTO MENU SCREEN
00:47:23 to 00:47:38
MO: You notice that there are nine buttons on the screen. Only
three of them work now. We haven't got around to the others
yet. I'll show you the link we've put in under... plumbing
00:47:38 to 00:47:50
CURSOR ONTO TOP BUTTON. SCREEN WIPES RIGHT TO REVEAL NEXT PAGE.
TEXT ON RIGHT WITH WHITE SPACES FOR PICTURES THREE TEXT ITEMS
HAVE HYPERLINKS.
MO: As you can see we still haven't put the picture in. Some of
my classmates are looking for pictures.
IAN: Still looking at this stage?
MO: It's very hard to find any...
```

Figure 3-3: C-video transcript with time stamps

AUDIOTAPED INTERVIEWS

Procedure

Interviews #4, #6 and #7 and Staff interviews were recorded using audio only. Interview sessions were conducted within a period of one or two

¹ Computer program developed by Jeremy Roschelle at U.C. Berkeley and distributed by Envisionology, 4104 24th St, Suite 344, San Francisco CA 94114, USA.

days if possible in order to provide some uniformity between them (as detailed in Table 3-1 and Table 3-2). The interviews were conducted in an office off the laboratory or in a staff office and were fairly informal and open-ended although a list of questions had always been prepared and were always asked — though not necessarily in the same order.

Evaluation session

Interview #4 was an extended interview with the whole group, evaluating the semester's work and commenting on aspects of the BS1 course. Issues which had arisen from the observations and demonstrations were raised for discussion by the groups. The Research Assistant was present for these group interviews as, in some cases, it was more comfortable for students to express their views in Cantonese. She was also able to contribute pertinent information arising from her knowledge of the issues and the special relationship she had developed with the groups while assisting them with system problems.

Final follow-up reviews

The Building Systems I course finished in May 1995. Some students stayed on over the Summer vacation and did more work on their projects and as a result the Chi Lin Temple model was salvaged from the system crash and completed. In the 1996 academic year, 11 of the students from the BS1 class enrolled in Building Systems II, which involved extending their computer skills into more complex projects such as 3D simulations for sunlight, ambient heat and noise. The work was done in groups, under the supervision of two Ph.D. students.

Interview #6 was conducted with the 11 BS2 students mid-way through the year to see how their views about computers in architecture and their skills in computer modelling had developed.

computer programs, such as 3D Studio, Photostyler and AME; 7 o'clock lists benefits of computer modelling in architecture; and 9 o'clock categorizes ways in which computing will be used in the coming project.

Mental models of the Server

Another form of graphic representation was obtained from students during Interview#2 when the researchers asked them to draw their mental image of the server and indicate the position of their files. This was at a time when students were experiencing particular difficulties with file loss. Figure 3-5 shows a reasonably accurate hierarchical model from Han, one of the group leaders, indicating that she has a clear picture of how the system works. By contrast, Figure 3-6 is Joan's somewhat whimsical attempt to anthropomorphize the computer into a representation of a human brain (complete with eyes).

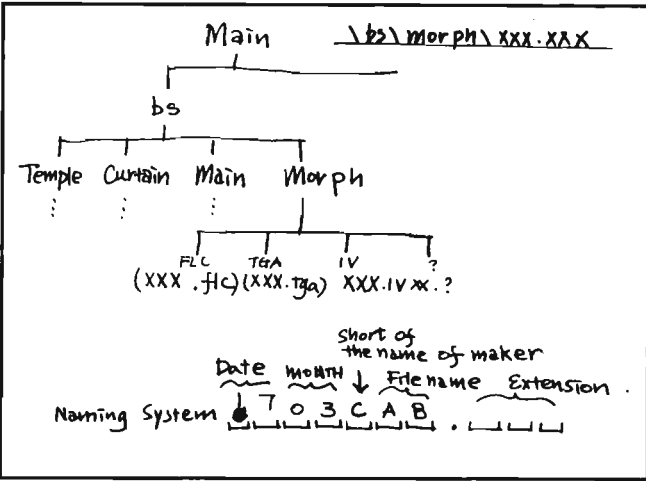


Figure 3-5: Mental model of server (Han)

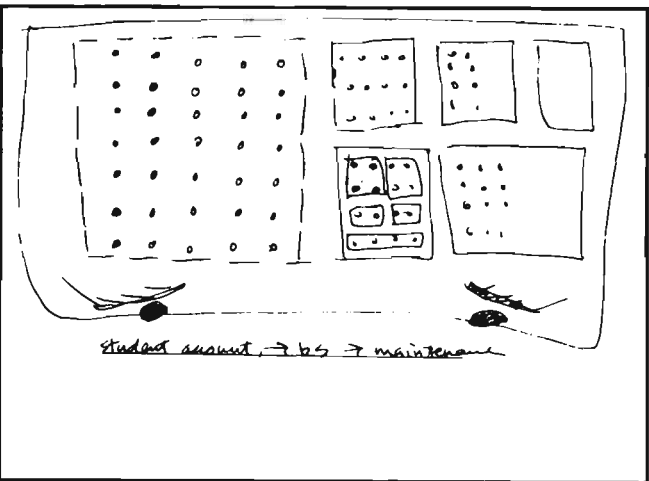


Figure 3-6: Mental model of server (Joan)

PFnets for concept mapping

Pathfinder networks (PFnets) result from semantic association tests in which subjects are asked to rank the relatedness of pairs of concepts. The resulting output is a graphic representation of the subject's concept map of a group of terms. It is a technique more commonly used with market research, but it proved to be a valuable tool, particularly when followed up by an interview in which the student was asked to interpret the resulting network.

At the commencement of Interview#7, students were asked to do a semantic comparison test using 11 words:

me, my group, computer, software, presentation, calculation, modelling, creative, research, learning, memory

These concepts had been distilled from earlier interviews and had all become low-level nodes in the NUD•IST data base. The aim of the exercise was to see how closely students related computers to themselves and their group as well as to concepts such as creativity and learning. An example of a resulting network produced by the KNOT computer program is shown in Figure 3-7. Pathfinder networks will be taken up again in more detail in Chapter 9: Structural Knowledge.

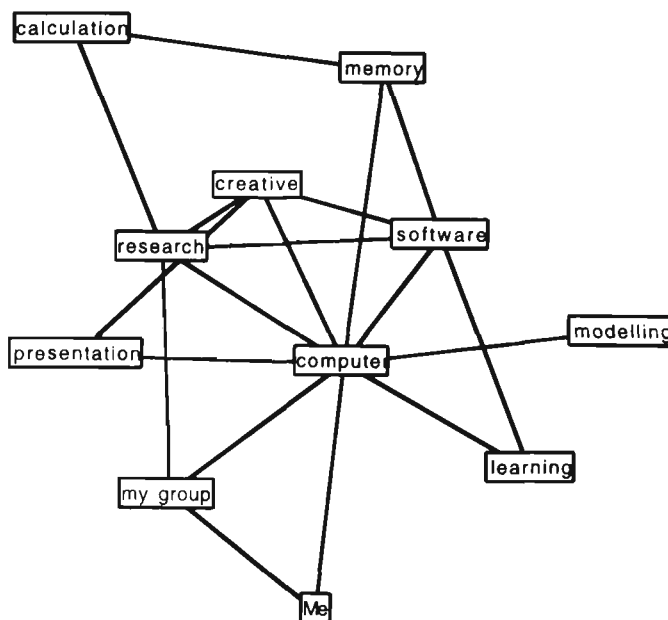


Figure 3-7: PFnet produced by KNOT

PROCESS DOCUMENTATION & OFF-LINE MATERIAL

Off-line material included both process documentation such as notes kept by developers and evaluators, incident reports, minutes of meetings, etc. and all non text media such as students' preliminary sketches, storyboards, etc. as well as scans, photographs, videotapes, screen captures, audiotapes, mind maps, etc. These were logged and indexed in the NUD•IST data base together with their locations and formats. As much as possible of this

Chapter 4

Student Characteristics

Summary: The research question concerned the interaction of student characteristics with the computing environment. This chapter describes the ways in which relevant characteristics of the students were derived from the data. These measures range from a statistically validated questionnaire (the SPQ) which enables comparison of the subjects of this study with equivalent Hong Kong tertiary students; to highly subjective data such as mental models of the computer system drawn by the students. The outcome of this chapter is a number of descriptive measures of students' approaches to learning, computing abilities and structural knowledge.

APPROACHES TO LEARNING

The term "approach to learning" was made popular by Marton and Säljö in the 1970s in their phenomenographic studies of tertiary student learning behaviour, to describe the *processes* which students follow in order to achieve learning outcomes. Using a qualitative, grounded theory methodology, based on interview and observation, they identified two approaches:

- **surface**, whereby students focus on what appear to be the most important topics or elements and strive to reproduce them; and
- **deep**, whereby students cast their net more widely, searching for analogies, expanding the topic to follow side-issues, and theorizing about what is learned (Marton, 1986; Marton and Säljö, 1976).

Biggs (1987), Ramsden (1988), Laurillard (1987) and others developed the concepts further in studies of learning styles. Biggs revised Marton's

definition slightly, describing an approach to learning as a *predisposition to adopt particular processes*. Biggs' view is that these predispositions have been developed by students in response to the demands of previous teaching/learning situations (Biggs, 1987; Biggs, 1991).

Biggs' methodology involved identifying and quantifying these predispositions by means of a standardized questionnaire which asks students to indicate how they usually go about learning. In addition to Marton and Säljö's *surface* and *deep* classifications, Biggs has added *achieving* approach. He further subdivides each of these three categories into two components: *motive* ("Why am I engaged in learning?") and *strategy* ("How, in that case, will I go about my learning?") "In other words, *how* you approach a task depends on *why* you want to approach it in the first place." (Biggs, 1992, p.9)

DEFINITIONS

SURFACE APPROACH

The motivation is extrinsic — one carries out the task because of either positively or negatively reinforcing consequences; e.g. the achievement of a paper qualification or the threat of a Fail mark in the subject. Because of this focus, surface learners tend not to see the interconnections between elements nor the meanings and implications of what is learned.

The surface approach is basically used ... to "get by". Such a strategy avoids detailed resource and strategy planning, monitoring, and in depth involvement with the task. It may meet the teacher's minimal requirements, as the student appears to expend some effort in the general direction of the task... (while) academically speaking, a surface approach cannot be satisfactory; existentially speaking a surface approach may be a sensible way of handling a difficult situation. (ibid. p.10)

DEEP APPROACH

The Deep Approach is based on intrinsic motivation or curiosity and a strategy which is aimed at seeking meaning. In the deep approach there is a personal commitment to learning, which means that the student relates the content to personally meaningful contexts, or to existing prior knowledge.

Study behaviour is usually by wide reading, discussion with teachers and other students, playing with the task, thinking about it constantly... In general the student taking a deep approach will:

- aim to possess a great deal of relevant content knowledge
- operate at a high or abstract level of conceptualization
- use optimal strategies for handling the task (p.11)

ACHIEVING APPROACH

The achieving motive is, as with the surface approach, focused on product: the satisfaction which comes from proficiency. The strategy involves maximizing the chances of success and while this may involve using the optimal strategy, this is the means rather than the end in itself (unlike deep strategy). According to Biggs, the nature of the engagement will depend upon what earns the most marks.

The achieving strategy concentrates on cost-effective use of time and effort, a rather cold-blooded calculation, involving organizational behaviours that characterize the model student: being self-disciplined, neat and systematic; planning ahead; allocating time to tasks in proportion to their importance, keeping clear notes, and all those other planning and organizational activities referred to as "study skills" (p.12)

While deep and surface approaches are mutually exclusive on any given task, an achieving approach may be linked to either surface or deep.

THE STUDYPROCESS QUESTIONNAIRE¹

The SPQ is the Hong Kong tertiary version of a questionnaire developed by Biggs in Australia in the 1980s in conjunction with the ACER. It consists of 42 items: each of the three scales is tested by 7 *motive* sub-scale items and 7 *strategy* sub-scale items.

APPROACH	EXAMPLE QUESTION
Surface Motive (SM) Extrinsic: avoid failure but don't work too hard.	<i>Lecturers shouldn't expect students to spend significant amounts of time studying material everyone knows won't be examined.</i>
Surface Strategy (SS) Focus on selected details and reproduce accurately	<i>I restrict my study to what is specifically set as I think it is unnecessary to do anything extra</i>
Deep Motive (DM) Intrinsic: satisfy curiosity about topic	<i>I find that many subjects can become very interesting once you get into them.</i>
Deep Strategy (DS) Maximize understanding: read widely, discuss, reflect	<i>In reading new material I am reminded of things I already know, and see them in a new light.</i>
Achieving Motive (AM) Achievement: compete for highest grades	<i>I really want to do better than anyone else in my assignments.</i>
Achieving Strategy (AS) Optimize organization of time and effort	<i>I regularly take notes from suggested readings and put them with my class notes on a topic.</i>

Table 4-1: Approaches to learning as tested on the SPQ

VALIDITY

The Australian SPQ was normed across six states in five universities and ten Colleges of Advanced Education but covered only the faculties of Arts, Science and Education. (Biggs, 1987). The Hong Kong version was normed across the five tertiary institutions and a wider variety of disciplines was sampled than for the Australian version. 3,298 First Year undergraduate students were involved and 1,778 senior students. As well as providing

¹ English only and English/Chinese versions of the SPQ as well as the scoring sheet are “freely available for use in research within Hong Kong, with full acknowledgment of the source” (Biggs, 1992)

overall norms for first and later year university and polytechnic students, the results were grouped into clusters of disciplines which shared similarities. A detailed description of the statistical background to the questionnaire and the various validation procedures followed can be found in Biggs (1992).

The tables of norms which Biggs developed from the various clusters results in a set of deciles which indicate to the user how typical a student's score is compared to the population to which that student may be considered to belong. Figure 4-1 shows the percentage of the population which falls into each decile, the deciles can be interpreted as follows:

1	Extreme: well below average, as the score falls in the bottom 10% of the population
2-3	Atypical: below average as the score falls within the bottom 11-30% of the population
4-7	Typical: average scores are within the middle 31-70% of the population
8-9	Atypical: above average in that 71-90% of the population would score lower than this
10	Extreme: well above average with over 90% of scores lower than this.

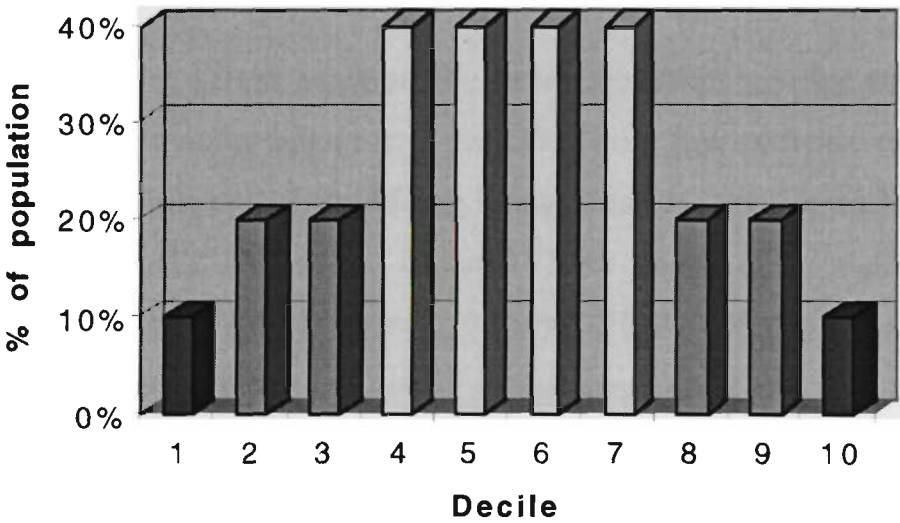


Figure 4-1: Decile scores on SPQ

ADMINISTRATION

An English version of the SPQ was administered by the research assistant to the 18 students who were present at the BS1 class on 14 January 1995. The results were disappointing — a number of students had misunderstood the questionnaire and filled it in incorrectly; several others had assumed it was meant to be anonymous and handed in their response sheets without any personal information. In all only 10 questionnaires were considered to be usable. A bilingual (Chinese and English) version of the questionnaire was re-administered by the author on 10 February, this time with a more careful introduction and a check to ensure that papers had been filled in correctly before the students were allowed to leave.

As a check, the 10 usable scores from the first administration were compared with the re-administered questionnaire and it was found that for 8 papers the raw scores varied by no more than 2% and the maximum variation on any scale was 6%. The results of the second administration were therefore considered to have high face validity and were used in the study.

SPQ RESULTS

The SPQ is a 5 point Likert scale so the seven question sets for each approach produce a score between 7 and 35. These raw scores were compared with a number of the Hong Kong clusters developed by Biggs, in particular *Clusters I.2 University General (First Year)*, *H.1 Polytechnic technical courses*, and *H.4 University general (Higher Years)*. The last of these proved to provide the closest fit to the average of the BS1 scores.

Figure 4-2 demonstrates the closeness of fit of the averaged scores from the study group to the H.4 cluster. The graph illustrates the extent of deviation from Biggs' normed scores for this grouping (the mid-point: 5). All six measures fall within the 3-7 typical range, so H.4 became the cluster against which the Building Systems students were subsequently measured.

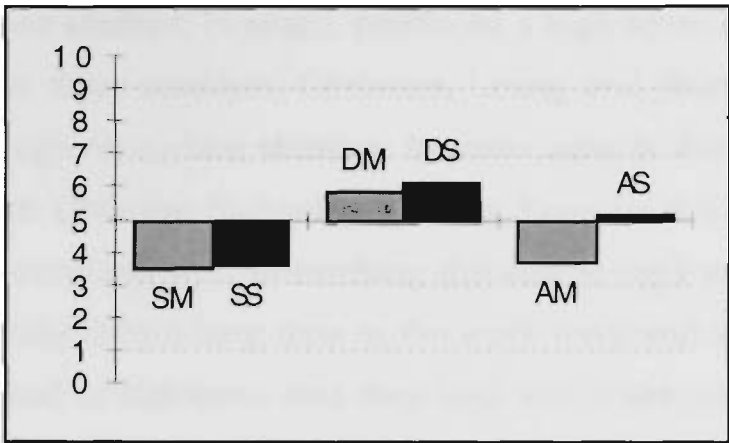


Figure 4-2: Deviations of class average scores from Biggs' H.4 cluster. The average is 5 and the normal range is 3-7.

Average figures are only valuable for comparison with other norms as they encompass a wide range of individual scores Table 4-2 to Table 4-7, provide more detailed breakdowns of scores across the six scales for the 18 students. For the sake of comparison, a visual greyscale coding mirrors the *typical - atypical - extreme* divisions of the graph in Figure 4-1.

SURFACE APPROACH

S M																		
Rank																		
Decile	1	1	1	1	1	2	2	3	4	4	4	4	5	5	6	6	7	9
Rawscore	9	11	13	13	14	15	16	17	18	18	18	19	20	20	21	21	22	26
Student	Desmond	Waiman	Yatman	Yin	Fai	Frankie	Joan	Wai	Bonita	Christina	Ronald	Shirley	Alice	William	Leung	Mo	Han	Howard

Table 4-2: SPQ scores on Surface Motive

Extreme Atypical Typical

S S																		
Rank																		
Decile	1	1	1	1	1	1	1	2	2	2	3	3	4	6	7	8	8	9
Rawscore	7	11	11	13	13	14	14	15	16	16	17	17	18	20	21	22	23	24
Student	Desmond	Waiman	William	Howard	Yatman	Fai	Joan	Ronald	Bonita	Yin	Alice	Frankie	Wai	Mo	Han	Christina	Leung	Shirley

Table 4-3: SPQ scores on Surface Strategy

As might be expected from a group of students undertaking a professional course, there is a high degree of skew in Surface results. 50% of the class provide atypical or extreme low scores on motive and 66% on

strategy. Only one student, Howard, produced a high score on surface motive; however three students, Christine, Leung and Shirley are comparatively high on surface strategy. In some aspects these were also atypical students: Christine had come to Hong Kong from Canada and was finding the pressure and style of teaching difficult to cope with; Leung had come back to study after a long time in the work force and was unsure of what was required of him (note that they both also score very high on deep motive); and Shirley, a fifth year student, was under much more pressure than her peers with a final thesis project due at the end of the semester. For such students Biggs' remark quoted above bears repeating: "(while) academically speaking, a surface approach cannot be satisfactory; existentially speaking a surface approach may be a sensible way of handling a difficult situation." (p.10)

DEEP APPROACH

DM																			
Rank																			
Decile	1	2	2	3	3	3	4	5	6	7	7	7	8	9	9	10	10	10	
Rawscore	14	17	17	19	20	20	21	22	23	24	25	25	26	27	28	31	32	33	
Student	Waiman	Desmond	Yatman	Alice	Howard	Mo	Bonita	Ronald	Shirley	Fai	Frankie	Yin	Han	Wai	Leung	Christina	Joan	William	

Table 4-4: SPQ scores on Deep Motive

 Extreme  Atypical  Typical

DS																			
Rank																			
Decile	2	3	3	4	4	5	5	6	7	7	7	7	8	8	8	9	9	10	
Rawscore	17	19	19	20	20	22	22	23	24	24	24	24	25	25	26	28	29	30	
Student	Mo	Alice	Waiman	Christina	Fai	Bonita	Frankie	Desmond	Han	Howard	Yatman	Yin	Ronald	Wai	Shirley	Leung	Joan	William	

Table 4-5: SPQ scores on Deep Strategy

The Deep Approach results present a more typical distribution, although Deep Motive seems to present something of a polarization, with four extreme scores: a 1 from Wai-man and 10 from Christine, Joan and

William. Each of these are interesting in themselves and can be examined in more detail in Appendix A: Profiles, but it is worth noting here that five of the six highest scorers on Deep Motive obtained the highest marks in their end-of-year assessments. William, who came to Hong Kong from Malaysia, had a deep interest in Chinese architecture and was a most valuable researcher. William’s score on Deep-Achieving, (combined scores from Deep and Achieving) is 10 which would seem to indicate a very dedicated and ambitious student. Unfortunately, he had a lot of problems later in the course and was ultimately unable to achieve his goals.

At the lower extreme on Deep Strategy is Mo, a high-level computer user and very talented student who, at the time the SPQ was administered, was expressing negative feelings towards both the course and his group who he felt were not pulling their weight. He felt that because he was the only member able to do the advanced programming required, he was “not learning anything new”, and reported that he found much of the work he was doing a “waste of time”.

ACHIEVING APPROACH

It is, perhaps, surprising that there are so many low scores on Achieving Motive (Tables 4-6 and 4-7). Over 70% are in the atypical or extreme range. A possible reason, suggested by Christina (score=2), is that at the time of the SPQ many students were concerned about the workload from this and other units and seriously considered that they were in danger of failing. High marks were the least of their concerns — simply passing would be totally sufficient!

A M																	
Rank																	
Decile	1	1	1	1	1	1	1	2	3	3	3	3	3	6	6	7	8
Rawscore	9	11	12	12	13	15	16	17	17	19	19	19	20	23	23	25	26
Student	Waiman	Yatman	Alice	Desmond	Joan	Yin	Bonita	Christina	Ronald	Fai	Frankie	Mo	Howard	Han	Wai	Shirley	William
																	Leung

Table 4-6: SPQ scores on Achieving Motive

Extreme

Atypical

Typical

A S

Rank																	
Decile	1	1	1	1	2	2	3	5	5	5	5	6	6	7	7	8	9
Rawscore	9	12	14	14	15	15	17	20	20	20	20	21	21	22	23	24	26
Student	Howard	Desmond	Waiman	Yatman	Alice	Christina	Ronald	Bonita	Joan	Wai	William	Fai	Frankie	Mo	Yin	Han	Leung
																	Shirley

Table 4-7: SPQ scores on Achieving Strategy

Three of the students who scored highly on Achieving Strategy — Mo, Yin and Han — were leaders of their respective groups; the fifth year student, Shirley (presumably) had developed better strategies for coping with the workload; the mature-age student Leung was back at university at considerable personal expense with a strong determination to succeed.

TRIANGULATION

With a sample size of only 18 subjects it would be difficult to make valid generalizations without establishing that they were representative of the wider student population in Hong Kong. The Study Process Questionnaire was designed to be used both for prediction and for diagnosis of learning difficulties, but in this study the scores serve an additional function of providing a normed and standardized base line measure against which we can compare our group to the population of Hong Kong tertiary students as a whole. The class average profile confirms that our subjects are typical in terms of approach to learning; the individual SPQ profiles, therefore, assist us to interpret data from other, more qualitative indicators such as interviews and observations, concept maps and PFnets described below.

COMPUTING KNOWLEDGE

The processes underlying learning to use a computer have interested researchers ever since the early days of the personal computer, although most of the reported studies have concerned human-computer interface (HCI) issues, and word processing in particular. Caroll and Mack (1984)

studied trained typists learning to use a word processor and showed that learning by reasoning and problem-solving (induction) required an effective representation of the problem space — the “desktop” metaphors of the Macintosh and Windows environments were influenced by this and similar studies at IBM and Xerox Research Centre. Biemans and Simons (1992) noted that expert computer users had developed better self-regulation (metacognitive) skills and were better able to apply those skills than novices, who required more outside help in the learning process. Ropo (1992) focused on the strategies which university students applied in learning to use a word processor and found that good learners focused on learning to understand the way the program and the computer worked. “They were also more goal-oriented than the poor learners, having better defined objectives for their work with the program.” (p.23) Koivula (1996), found the same distinction applied with much younger learners — the difference between good and poor learners was defined by the nature of the strategies which they applied. Successful learners applied inductive strategies; less successful learners relied on outside assistance.

A large proportion of the research into computer skills and HCI has been carried out using videotaped observation and talk-aloud protocol studies (e.g. Sasse 1991), although the ultimate aim of some of this work has been to develop standardized tests of computer competence. For example, in designing a standardized evaluation for text editors at Xerox Research Centre, Roberts and Moran (1989) made use of comparisons between experts and novices in order to develop a rating scale.

The objectives of the present study are not identical to the examples above, as we are concerned here with students adapting far more complex computer software to their particular learning and creative needs (all the students were already familiar with word processing), but the

methodology was transferable. We employed demonstration², video observation and talk-aloud protocols to record the students' efforts. We also made use of experts in order to establish a benchmark: Waycal, a Ph.D. student and tutor on the course, and an expert in 3D computer modelling, was also asked to demonstrate to the researcher how to use AutoCAD and 3D Studio, and to talk as he worked. From his transcript 135 concrete conceptual terms used in computer modelling were identified (e.g. adjacent, alignment, ambient, axis, bit, bitmap, boolean, boundary, box, ... etc.); and 35 verbs describing procedures were identified (e.g. add, adjust, assign, associate, automate, build, calculate, ... etc.).

The video recordings of the student demonstrations were transcribed and key frames extracted to illustrate the progress and the results of the demonstrations. Each of the transcripts was mind mapped to isolate the key concepts and procedures as described by the students (see p.4:59). Using these concepts as classifiers, word lists were extracted from the transcripts. Based on the mind maps and word lists, students' factual knowledge (of interface, computer terminology, modelling terminology) computer skills (in producing a 3D model) and awareness of contextual issues (appropriate software, place of 3D in the design process, computers as productivity tools) were classified as High, Average or Low.

DECLARATIVE KNOWLEDGE

The score was derived from the computer demonstration interviews and was based on the percentage of concrete terms from Waycal's interview which appeared in individual student transcripts. The classification and indexing of this data is treated in detail in Chapter 5.

² "Demonstration", in this context, refers to the technique of asking the student to demonstrate something to the researcher or to another student.

<i>The percentage of the terms from Waycal's interview which also appeared in student transcripts (variations of forms and similes were excluded).</i>	
3 (High)	> 60%
2 (Average)	30-60%
1 (Low)	< 30%

PROCEDURAL KNOWLEDGE (SKILL)

<i>Based on level of competence displayed in the demonstration</i>	
3 (High)	<ul style="list-style-type: none">• Could create, manipulate and render complex 3D shapes• Was confident in software commands for all relevant applications• Knew and used software shortcuts• Could confidently transfer files from one software to another
2 (Average)	<ul style="list-style-type: none">• Could create required 3D shapes and carry out standard operations on them.• Knew most common software and system commands• With assistance could transfer files from one software to another
1 (Low)	<ul style="list-style-type: none">• Could create only basic 3D shapes or 2D shapes• Was uncertain about software commands• Had difficulty transferring files from one software to another• Required assistance to retrieve files from the server.

CONTEXTUAL KNOWLEDGE

<i>This was a more subjective measure, based on what students said about computers with regard to their projects and to their architectural studies in general.</i>	
3 (High)	<ul style="list-style-type: none">• Had a clear knowledge of the functions and benefits of computers in the design process (e.g. presentation, simulation, storage)• Was able to envisage ways in which different software can be linked to accomplish a complex task (e.g. designing - rendering - animation) Was able to appreciate ways in which computer modelling can facilitate cognition (e.g. through deconstruction, simulation, visualization)
2 (Average)	<ul style="list-style-type: none">• Appreciated the usefulness of computers in architecture (although not necessarily willing to use them)• Was aware of the qualities of different software, but had limited experience (e.g. 3D Studio, Inventor)• Could discuss uses for computing in aiding visualization of designs, particularly for clients

1 (Low)	<ul style="list-style-type: none">Disliked computers and preferred not to use themWas unfamiliar with any software other than that taught in earlier years (e.g. earlier versions of AutoCAD)Was not aware of any particular uses for computing other than replication (i.e. saving time and effort)
---------	--

COMPUTING KNOWLEDGE PROFILES

Table 4-8 shows the resulting knowledge profiles for all students except Lun (who arrived in the course after the beginning of term, but was included in the later interviews).

COMPUTER KNOWLEDGE & SKILL																		
Declarative	1	2	1	3	1	2	1	3	1	2	3	1	2	3	3	1	2	3
Procedural	2	1	2	3	1	2	2	3	1	2	3	2	2	3	2	1	2	3
Contextual	1	1	2	3	1	2	3	3	1	3	3	1	2	3	1	1	2	2
Student	Alice	Bonita	Christina	Desmond	Fai	Frankie	Han	Howard	Joan	Leung	Mo	Ronald	Shirley	Wai	Waiman	William	Yatman	Yin

Table 4-8: Student profiles on computing knowledge

STRUCTURAL KNOWLEDGE

DEFINITIONS

Structural knowledge is a hypothetical construct. It has been referred to by many different theorists under a number of names: internal connectedness, integrative understanding, conceptual knowledge, “the integrated storage of meaningful dimensions” (Tennyson and Cocciarella, 1986) and cognitive structure. Preece (1976) believed that individual differences in behaviour are attributable in part to differences in an individual’s cognitive structure. According to Jonassen (1993) cognitive structure evolves individually from the ascription of attributes to objects in the world which enables the definition of structural relations among concepts (p.5) For Lakoff (1987), this ascription of attributes, or categorization, is central to both language and to thinking.

Categorization is not a matter to be taken lightly. There is nothing more basic than categorization to our thought, perception, action, and speech. Every time we see something as a *kind* of thing... we are categorizing. Whenever we reason about *kinds* of things — chairs, nations, illnesses, emotions... — we are employing categories.

Whenever we intentionally perform any kind of action, say writing with a pencil, hammering with a hammer or ironing clothes, we are using categories. (p.5-6)

Since the days of Aristotle, categories have been thought to be unproblematic and well understood. Objects were considered to be in the same category if they had certain things in common, and the common properties were what defined the category. For three centuries categorization was accepted as a given and was taught in many disciplines as an “unquestionable, definitional truth.” (p.6) In the Western tradition categorization was assumed to be disembodied and abstract — distinct from the body, perception, and culture as well as from the mechanisms of imagination such as metaphor and mental imagery.

It has only been in this century that the theory of categorization has gradually become central to a wide range of disciplines, among them linguistics, anthropology, sociology and learning theory. Within cognitive science, categorization has become a major field of study, thanks primarily to the work of Eleanor Rosch (1978) who demonstrated through empirical study that categories are far from being uninfluenced by perception and culture. Rosch showed that in all categories there are “best examples”, which she called “prototypes” and that these are influenced by a range of human capacities.

SCHEMAS

Schema theory contends that categorization is central to knowledge, and the concept of the schema has been influential in both cognitive

psychology and artificial intelligence, under that name as well as under labels such as “script”, “frame” and “concept” (Bartlett, 1932; Minsky, 1975; Piaget, 1987; Rumelhart, 1980; Schank and Abelson, 1977). The premise underlying the notion of schemas is that information about the likely properties of the environment is stored in memory in clusters that can be accessed as large units that can serve to generate plausible inferences and problem solutions.

“Meaning does not exist until some structure, or organization, is achieved” (Mandler, 1983) Without structure, according to Mandler, mental constructs could not be formed because nothing could be described. Each object may have an identity but it could have no relation to anything else. Without structure, abstract knowledge would be impossible. Therefore, the deeper a domain is understood, the more abstract the structure must be.

MENTAL MODELS

Kylönen and Shute (1989) developed a taxonomy of learning skills which include (from bottom-up) propositional statements, schemata, rules, general rules, skills, automatic skills and mental models. They see mental models as the most complex type of knowledge and recommend measuring them with sophisticated simulations and performance tests. However, as Jih and Reeves (1992) point out, the mental models constructed by learners are not easily observable. Sasse (1991) designed a series of studies to elicit mental models of computing, using methods such as observation of learners, asking learners to teach others and questioning learners on their expectations of how the program will behave. Such methods have been employed elsewhere in this study to elicit computer knowledge (see, for example, p.4:52).

Structural knowledge, however, is normally described using graphic representations rather than words. These representations range in format

from algorithms to Venn diagrams; from classification tables to concept maps. Buzan (1993) has popularized a technique he calls "mind mapping" both as a means of revealing categories and making links between them, and as a memory aid. Evans and Danserau (1991) have promoted the use of "knowledge mapping" techniques both for college-level study and for communicating the outcomes of study. The most comprehensive treatment of these representational techniques is contained in Jonassen, Beissner and Yacci's (1993) *Structural Knowledge*, which collects together in one book a variety of means by which these constructs can be reified.

In this study, three concept mapping techniques were employed: Buzan mind maps, free form mental models and Pathfinder networks (PFnets). While such graphic representations are not always easy to interpret, and it is doubtful that valid conclusions could be drawn from any one of them, they were most revealing when triangulated with the data from the SPQ, the computer modelling test, interviews and the final marks.

MIND MAPS

Buzan's mind mapping technique is a practical application of Mandler's proposition that meaning does not exist until some structure, or organization, is achieved. It was first devised as a means of assisting students to categorize and memorize concepts by making clear the links between them. The technique was employed in this project in the first instance as a means of organizing the data from the computing knowledge demonstrations and developing categories for the NUD•IST tree. It became clear that by using clock-face reference points to represent certain categories, the map could present a graphic comparison between students with different levels of declarative and structural knowledge.

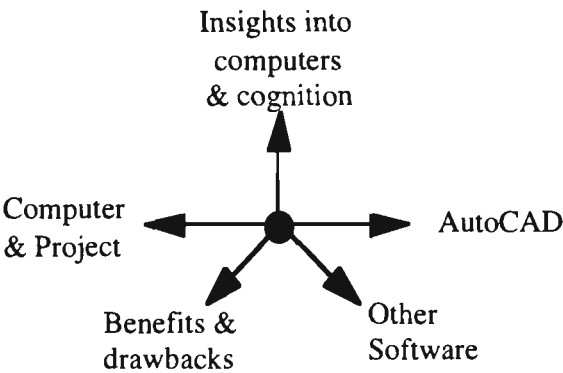


Figure 4-3: Basic mind map categories

Five basic categories were developed: 3 o'clock: what students knew about AutoCAD; 5 o'clock: knowledge of other software; 7 o'clock: what they said about the benefits and drawbacks of CAD in architecture; 9 o'clock: how they proposed to use 3D computer modelling in the project; 12 o'clock was used to categorize particular insights into computers and learning. Figure 4-4 and Figure 4-5 show two of the maps which were drawn from the data.

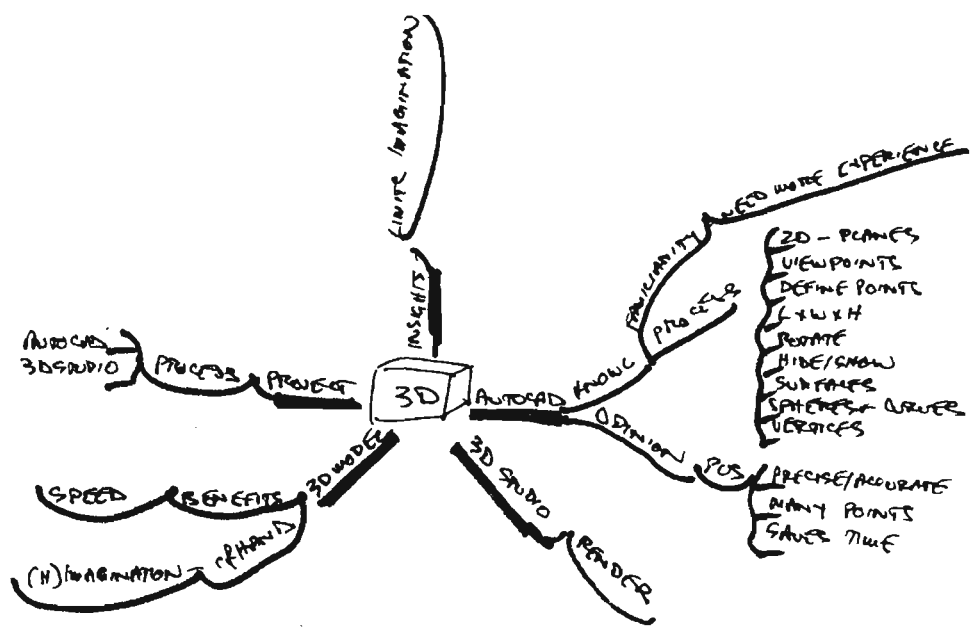


Figure 4-4: Buzan mind map - Howard

Figure 4-4 is from a student with quite a lot to say about 3D computer modelling. The branch at 3 o'clock demonstrates a comprehensive knowledge of AutoCAD (familiarity, a wide range of processes and opinions) as well as a little about 3D Studio (5 o'clock). The

branch at 7 o'clock records opinions on the benefits of computer modelling as a tool in architecture (it is faster, but less spontaneous than drawing by hand), and 9 o'clock records ways in which computer modelling will be used in the project. 12 o'clock records the "insight" that the student believes that using computers can limit the imagination.

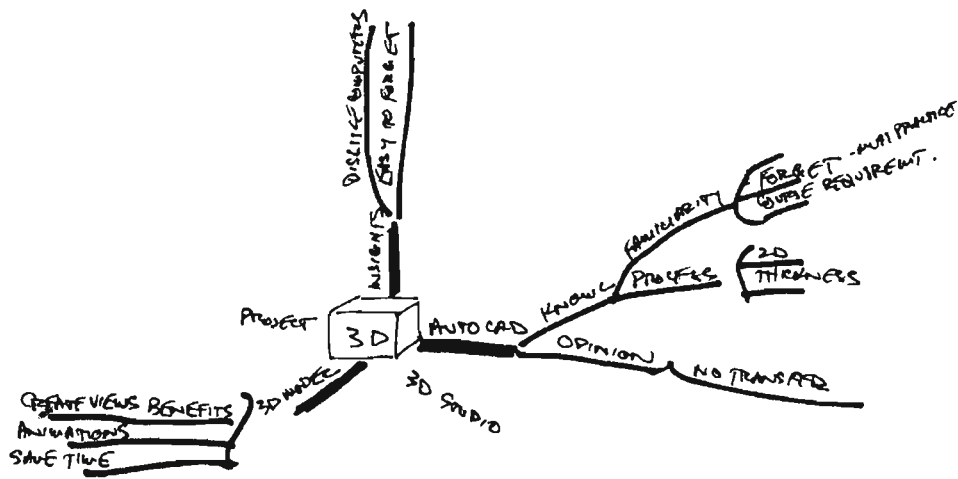


Figure 4-5: Buzan mind map - Fai

By contrast, Figure 4-5 is from a student with limited knowledge of AutoCAD and virtually nothing to say about other software . He has some opinions on the value of computer modelling in architecture. The Insights branch (12 o'clock) records that he disliked using computers and thinks it is too early to predict how useful they might be.

The mind maps for all the students can be examined, and compared with their computing knowledge scores, in Appendix A: Profiles.

MENTAL MODELS OF THE SERVER

The laboratory's main server held a great number of applications as well as files belonging to different classes as well as individual students and staff members. All files required password access (normally student number). Most students seemed reasonably confident of the structure from the Building Systems sub-directory ('bs') down, but not so many appeared to be aware of what else was on the server. Many students had difficulty logging on and finding their directories and files without assistance.

In the following exchange between Han and Raymond (the lab technician), Han was trying to retrieve her group's files in order to demonstrate them to the researcher. Her dilemma is typical of the problems students were experiencing at that time.

HAN: I have moved it to there and then I realized that we haven't got the "fli" here anymore. I have moved it to the subsystem of Building system called "bs", how can I get it back?

RAYMOND: You can go back to that directory and retrieve it.

HAN: I don't know where is the sub-directory so I can type it in here, isn't it?

RAYMOND: Where did you move it to?

HAN: There are four ... no, six once you open the building system icon.

RAYMOND: So, you know where it is, why don't you try it then?

HAN: I just want to know is it under this "bs" icon?

RAYMOND: Yes.

HAN: Let me open this icon. Ah, this one!

RAYMOND: Yes.

HAN: Then, should I type in the name of the file here?

RAYMOND: No, you use this program to run it.

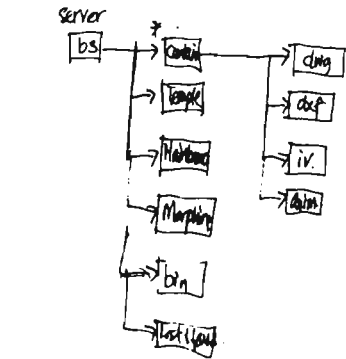
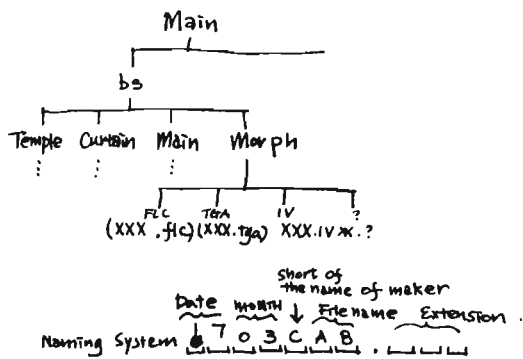
HAN: OK!

RAYMOND: The full title of the file.

HAN: Oops, the name is changing..... should I close it?

In an attempt diagnose the difficulty students were having, we asked them to draw a diagram of their mental image of the central laboratory server and indicate where they thought their files were located within the hierarchy. The resulting mental models can be classified in two ways: (a) the level of detail, (and its accuracy) and (b) the way in which they structure the information graphically. The exercise produced three basic styles of structure which provide a revealing indication of the levels of students' structural knowledge.

code devised by the Morphing group to identify their files. (This was drawn a fortnight after the above exchange.) Most responses were at this level of detail, which reinforced the observation that while students were aware of the structure of their own sub-directories, most were hazy at best about the server as a whole. At the time of this exercise most of the “average” students (on the procedural scale) still required assistance with logging in.



EXPLANATORY

Some students were unable to adequately describe the server structure with a diagram, but needed to elaborate with text or use representational drawings.

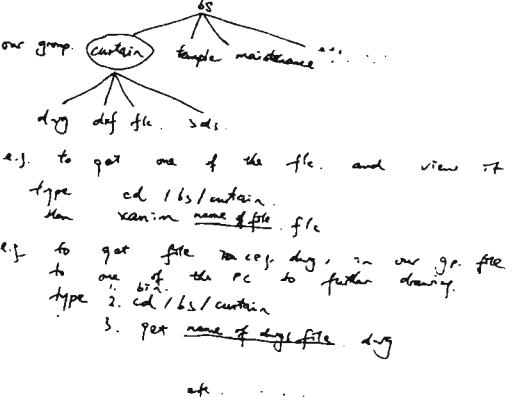
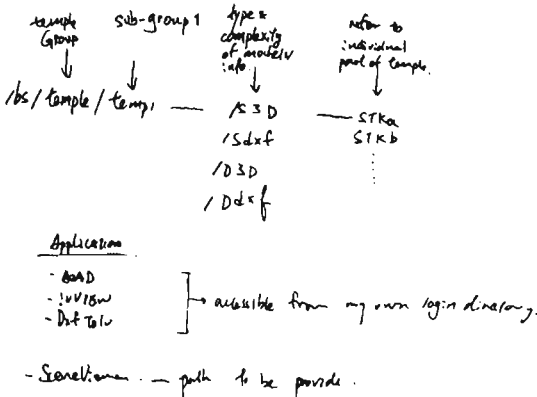


Figure 4-10: Explanatory model - (Desmond)

Figure 4-11: Explanatory model - (Fai)

Desmond (Figure 4-10) drew a left-to-right sequential diagram of the structure together with a gloss, explaining the codes used for “type and complexity of models” and the file names for the “individual parts of the temple (project)”. He also lists the applications he uses. Fai (Figure 4-11) has written an essay illustrated with a diagram. It provides step-by-step instructions on how to log in and reads like a note he wrote himself after having had it explained to him by a tutor or classmate.

FANCIFUL

Some students appeared to have no concept of the server structure at all and resorted either to representing the task in a different way (e.g. by drawing the laboratory lay-out) or creating a whimsical representation of the computer system.

Representational

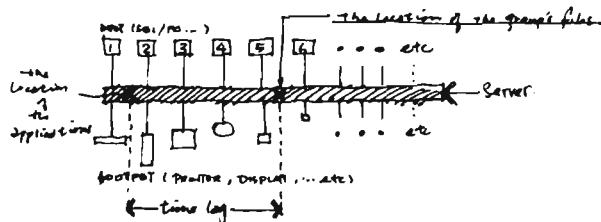
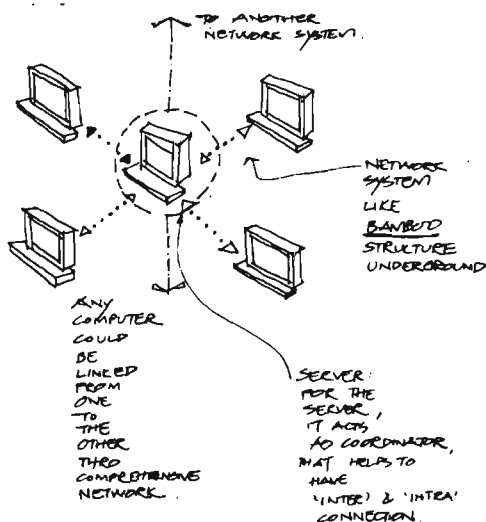


Figure 4-12: Fanciful-representational model - (Frankie) Figure 4-13: Fanciful-representational model - (Yat-man)

Frankie's very “architectural” drawing (Figure 4-12) is meant to represent the computer laboratory, showing the central server (“acts as a coordinator that helps to have ‘inter’ and ‘intra’ connection”) and the network (“like bamboo structure underground”). Yat-man (Figure 4-13) has also drawn a picture of the computer lab, showing the layout of the work stations along a central spine with the server at one end and the

“location of the application” at the other and a “time lag” between them. Neither Fai nor Frankie were cognizant of the file structure of the server.

Whimsical

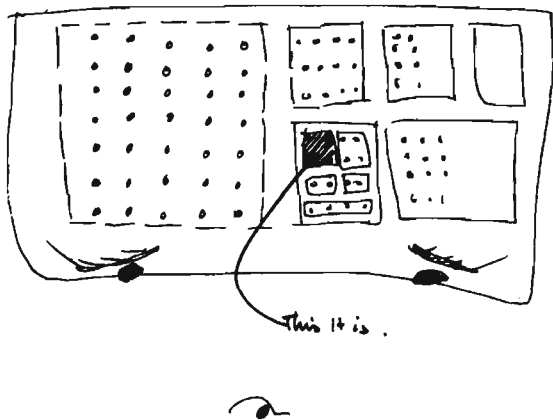


Figure 4-14: Fanciful-whimsical model (Joan)

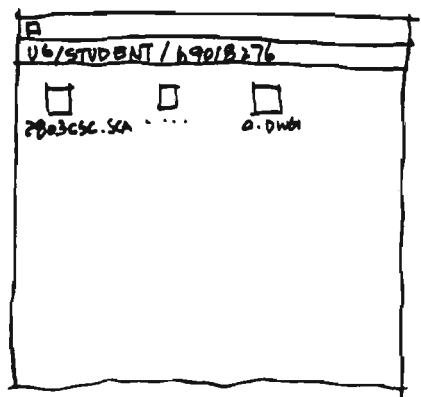


Figure 4-15: Fanciful-whimsical model (Wai-man)

Joan’s (Figure 4-14) anthropomorphic picture depicts the computer as a human brain (she explained that it was meant to be her brain) complete with eyes and a nose and a helpful arrow indicating that the Maintenance files reside in the left frontal lobe (“Here it is”). Wai-man (Figure 4-15) took a literal approach and drew a picture of the computer screen just after she has logged in, showing her student ID and a number of files ready to be opened.

SUMMARY

Table 4-9 classifies the result of this exercise, indicating (a) the level of accurate detail on a 5 point scale; (b) a description of their mental models classifications above.

- | | |
|---|--|
| 5 | <i>A comprehensive picture of the structure from Root level down, showing locations of applications and files of all groups, plus details of project files</i> |
| 4 | <i>Shows accurate picture from bs down to project files, with all sub-directories of subject's project</i> |
| 3 | <i>Model is factually correct, but lacks detail. e.g. only shows project sub-directories in any detail</i> |
| 2 | <i>Is understandable in terms of the server structure, but is incorrect or does not answer the question</i> |
| 1 | <i>Bears no relationship to the server structure</i> |

Student	Accuracy	Description
Alice	3	Hierarchical, Root down, with minimum detail
Bonita	4	Hierarchical, bs down, details of project sub-directory
Christina	3	Hierarchical, bs down, details of group & project files
Desmond	4	Explanatory, bs down, details of project sub-directory
Fai	3	Explanatory, bs down, minimal details of sub-directory
Frankie	2	Representational, shows layout but not file structure
Han	5	Hierarchical, Root down, with details of file codes
Howard	5	Hierarchical/representational, Root down, shows everything
Joan	1	Fanciful, shows computer as brain
Leung	3	Hierarchical, Root down, shows minimum detail only
Mo	3	Hierarchical, bs down, shows only basic structure
Ronald	3	Hierarchical, bs down, shows only project group files
Shirley	3	Hierarchical, bs down, shows only basic structure
Wai	5	Hierarchical, Root down, shows complete server structure
Wai-man	1	Fanciful/representational, shows screen image
William	-	Not available
Yat-man	2	Fanciful/representational, information basically incorrect
Yin	4	Hierarchical, bs down, shows project sub-directories only

Table 4-9: Student results on Mental Model exercise

PFNETS FOR CONCEPT MAPPING

Pathfinder networks (PFnets) are produced from semantic association tests in which subjects are asked to rank the relatedness or lack of relatedness of pairs of concepts on a scale of 1 to 9. The resulting output is a graphic representation of the subject’s concept map of a group of terms.

Lakoff (1987) lists a number of experimental paradigms for studying categories of physical objects and abstract concepts on which subjects have been shown to give consistent goodness-of-example ratings. Two of these paradigms are relevant to this exercise:

Asymmetry in similarity ratings: Less representative examples are often considered to be more similar to more representative

examples than the converse. e.g. in studies carried out in the USA Americans generally believe that the USA to be a highly representative example of a country. In experiments where subjects were asked to give similarity ratings for pairs of countries, the following asymmetry was common: subjects considered Mexico to be more similar to the USA than the USA to Mexico.

Family resemblances: Wittgenstein had speculated that categories were structured by what he called "family resemblances". Rosch showed that what philosophers took as a matter for a priori speculation could be demonstrated empirically. Categorizing family resemblances as perceived similarities between representative and non-representative members of categories. Rosch showed that there was a correspondence between family resemblances and numerical ratings of best example derived from the above experiments. (Lakoff, 1987, pp. 42 & 264; Rosch, 1978; Rosch and Mervis, 1975)

Pathfinder networks employ both of these techniques: providing numerical measures for family resemblances and logging asymmetry, then drawing a network where links record the relative importance accorded to relatedness and symmetry is represented in the nature of those links. The recursive statistical methods employed to do this can produce a number of outputs, including 2D and 3D multidimensional scales, spring scales and PFnets. It is a technique now commonly used in market research, but has not to our knowledge been widely used in learning research. Here, it proved to be a valuable tool, particularly when followed up by an interview in which the student was asked to interpret the resulting network. The software used was KNOT³ a knowledge network organizing tool for the Macintosh, which generates a variety of graphic and statistical outputs from the data, including PFnets and multidimensional scales.

³ KNOT is available from Interlink, Inc. P.O. Box 4086 UPB, Las Cruces, NM, 88003-4086.

The semantic comparison test employed the following 11 concepts, some concrete, some abstract:

me, my group, computer, software, presentation, calculation, modelling, creative, research, learning, memory

These concepts had been distilled from earlier interviews and had all become low-level nodes in the NUD•IST data base (see Chapter 5). The aim of the exercise was to see which of the terms would be most *representative* and how closely students related computers to themselves and their group as well as to concepts such as creativity and learning. The reason for restricting the number of concepts to only 11 is that matching every term against all others generates 55 pairs of words ($n-1 + n-2 + \dots + n$) and based on previous experience of administering the KNOT exercise, this was an effective maximum — beyond 55, students tend to lose concentration.

HOW PFNETS ARE PRODUCED

The Pathfinder program in KNOT defines a network (a PFnet) given estimates of the proximities for pairs of entities. The entities correspond to the nodes of the generated network, and the links in the network are determined by the patterns of proximities. The links in the network will be undirected (edges) if the proximities are symmetrical for every pair of entities. Symmetrical proximities mean that the order of the entities is not important, so the proximity of x and y is the same as the proximity of y and x for all pairs of x, y . If the proximities are not symmetrical for every pair, the links will be directed (arcs).

Pathfinder uses two parameters.

1. The q -parameter which constrains the number of indirect proximities examined in generating the network. (The q -parameter is an integer value between 2 and $n-1$, inclusive where n is the number of nodes or items).

-
2. The r -parameter defines the metric used for computing the distance of paths. The r -parameter is a real number between 1 and infinity, inclusive.

A network generated with particular values of q and r is called a PFnet (r, q) . Both of the parameters have the effect of decreasing the number of links in the network as their values are increased. The network with the minimum number of links is obtained when $q = n-1$ and $r = \text{infinity}$, i.e. PFnet $(\text{inf}, n-1)$. This is the set of parameters that was used in this study.

Further information on Pathfinder networks and several examples of the application of PFnets to a variety of problems can be found in Schvaneveldt (1990)

CLASSIFYING PFNETS

Analysis of the nets produced by the students showed that there were four characteristic patterns, typified by both the number of connections and the shape of the net — the way the connections were arranged. These are illustrated on the following pages.

The tables compare individual PFnet patterns with two other student profile scores: *Table 4-8: Student profiles on computing knowledge*, and *Table 4-9: Student results on Mental Model exercise*.

“Cat’s cradle” pattern

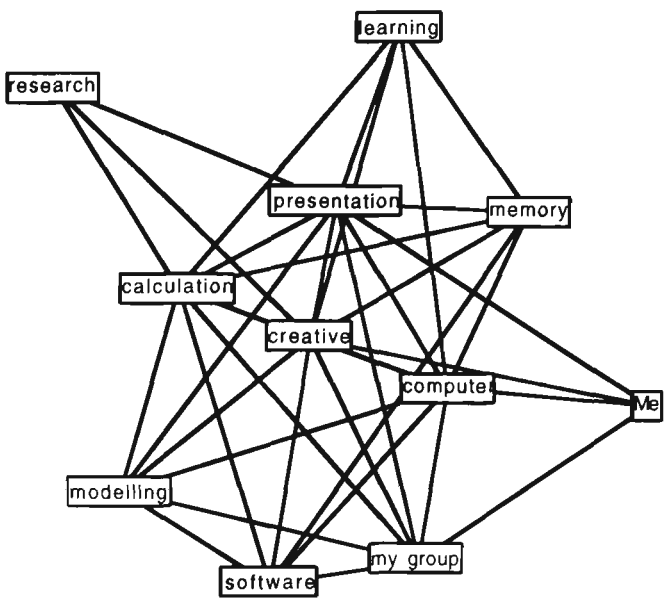


Figure 4-16: Cat’s cradle PFnet

This pattern (named after the children’s string game) has the largest number of connections. The pattern is produced when a subject connects every concept equally to every other concept (the numerical score is immaterial). All links are approximately symmetrical. The cat’s cradle shape indicates either an exceptionally deep approach (where the student genuinely considers everything related), or an inability to make decisions.

Student	Computing knowledge Table 4-8			Accuracy Table 4-9
	Declarative	Procedural	Contextual	
Alice	Low	Average	Low	3
Joan	Low	Low	Low	1

Table 4-10: Comparative scores for students with Cat’s Cradle pattern

“Branching” pattern

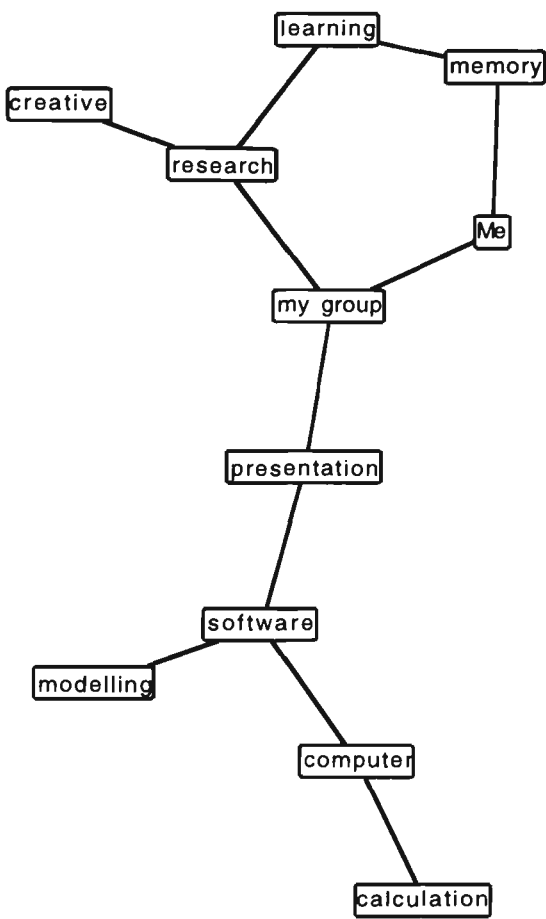


Figure 4-18: Branching PFnet

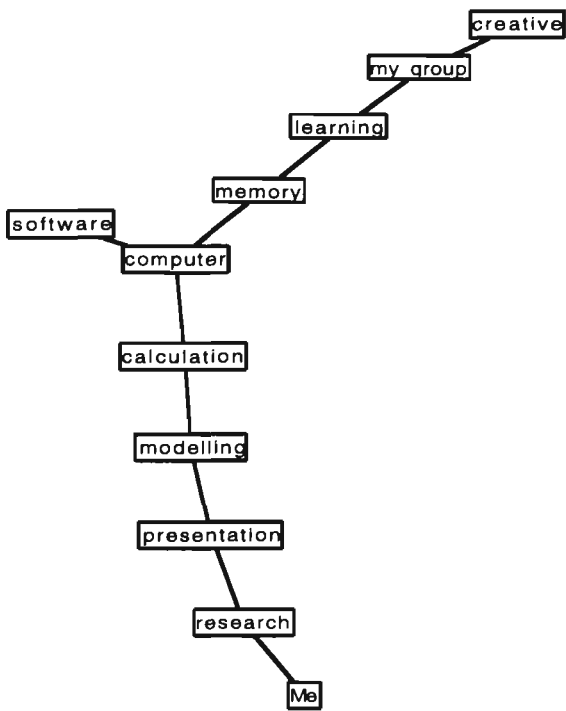
The net is well-structured and it is easy to distinguish a hierarchical relationship between the concepts. The most representative concepts appear as nodes and their relationships to the other terms are distinct. Typically there are two or three most representative nodes. In this example a computing vs. personal dichotomy is apparent: the two most representative terms are software (linked to computer, modelling, and calculation); and group (linked to me, memory, learning, research, and creative). Additionally, the two nodes are linked by presentation — a surprisingly literal picture of the way in which the BS1

course operated.

Student	Computing knowledge Table 4-8			Mental model Table 4-9
	Declarative	Procedural	Contextual	
Wai	High	High	High	5
Han	High	High	High	5
Christina	Low	Average	Average	3
Yin	High	High	High	4
Yat-man	Average	Average	Average	2
Bonita	Average	Low	Low	4

Table 4-12: Comparative scores for students with Branching pattern

“Linear” pattern



Could be characterized as a branching pattern with the minimum number of nodes. This example has just one: computer. No term appears to be more representative than any other and all links are asymmetrical, so the concepts fall into a straight line. Distance rather than proximity is the most revealing aspect of this pattern and one can compare the concepts by counting how many links one is from another e.g. this student seems to have a low opinion of her own creativity because me is 9 links away from creative. However, even in

Figure 4-19: Linear PFnet

this quite extreme example there is an indication that one concept, computer, is a little more representative than the others.

Student	Computing knowledge Table 4-8			Mental model Table 4-9
	Declarative	Procedural	Contextual	
Wai-man	High	Average	Low	3
Ronald	Low	Average	Low	1

Table 4-13: Comparative scores for students with Linear pattern

INTERPRETATION

It could be argued that the Branching shape indicates a student with a very clear view of the way in which concepts are related — in other words a high degree of what Mandler (1983) and Jonassen, Beissner and Yacci (1993) defined as structure. The Web shape appears to identify students who see the world in terms of one or two main concepts, e.g. computer, presentation, or me and relate to other concepts through these. Such students are focused, and may be skillful, but are probably less aware of the

big picture. The Cat's Cradle and Linear shapes may indicate students with a comparatively low degree of structural knowledge. One would not expect them to be as academically successful as the other two categories.

This theory is supported to some extent by the tabular information. There appears to be a correlation between students who score within the range 3 - 5 on mental model accuracy and either Branching or Web PFnets. Most of these students also have average or High scores on Contextual Knowledge. The Cat's Cradle and Linear shapes correlate with accuracy scores of 3 - 1 and a Low Contextual Knowledge score.

The PFnets for individual students can be compared in Appendix A: Profiles, together with their SPQ scores, computer competence scores, mind maps and mental models. In the final chapter we will ask whether by triangulating these indicators with other data, we can come to any conclusions about the interaction of student characteristics, computers and cognition.

CONCLUSION

This chapter has provided a number of descriptive measures of student characteristics: the SPQ scores furnish a picture of each student's approach to learning; the mind map and computer skills scores indicate the entry level of each student in terms of declarative, procedural and contextual knowledge of computing; and the mental models and PFnets contribute a picture of students' structural knowledge of the computer system and the ways in which they structure relationships between themselves, their classmates, the computer and their learning tasks. Consolidated *Profiles* of each student have been collected at Appendix A.

Chapter 5

Dealing With Unstructured Data

Summary: 115 documents comprising approximately 17,500 text units of transcribed interviews and observations were collected in the course of the study. This chapter describes the NUD•IST software which was used to organize the data and the methods by which it was indexed, using a data-driven, or grounded theory approach to classification. The indexing system remained fluid for much of the 18 months of the study, but was finally reduced to just five basic classifications, or nodes: Base data, Profiles, Computing knowledge, Domain knowledge, and Cognitions; each of these being subdivided into hierarchical layers of sub-nodes. This chapter describes these sub-nodes, provides examples of transcripts, and statistical information on the numbers of text units and numbers of documents indexed at each of them. The final section describes how the data base was searched in order to produce the *Outcomes* of Chapters 6 and 7.

QUALITATIVE RESEARCH METHODS

The outcome of a purely quantitative research project is a standardized and verified set of figures in an approved statistical format. By contrast, qualitative research involves the gradual development of ideas about data and the exploration of these ideas. Sometimes the project begins with descriptive categories, derived from research or intuition; more often categories are derived from the data during the project and linked in ways that describe the data. New theories are constructed and tested by exploring their links with data.

Researchers normally proceed using some or all of the following methods:

- creating categories for thinking about the data, from prior theory and/or ideas emerging from the data;
 - indexing or coding segments of documents at these index categories so all material about a category can be retrieved;
 - storing factual information about documents, cases, people and sites;
 - recording ideas about indexing categories and developing these as understanding grows;
 - using index references for bringing together linked passages of text for interpretation, detailed description, theory testing or analysis;
 - sorting and re-sorting data to locate patterns;
 - expressing, exploring, testing and validating theories about the data.
- (Fielding & Lee, 1991; Miles & Huberman, 1994)

Qualitative researchers typically collect transcript material, divide it up by content and file it under descriptive headings. The same piece of information may need to be cross-indexed under a number of headings and before computer programs enabled this to be accomplished electronically it was done with the aid of photocopier, scissors, adhesive tape, manila folders and a cataloguing system based on library cards and memo paper.

NUD•IST

NUD•IST (Non-Numeric Unstructured Data - Indexing, Searching and Theorizing) accomplishes the same ends using a PC instead of a filing cabinet and it speeds up the searching and re-indexing process considerably. Clerical stages of research, which include recording, storage and coding, are handled in separate document and index files. The data documents (known as "Rawfiles") remain "clean" of coding so that they can be re-examined (and re-coded if necessary) at any time. Analytical work, comprising exploration, memo-writing, data retrieval, and the creative building of theory, takes place in the interplay of the original text with the conceptual structure used for and created by its exploration. With

this type of structure, indexing is less a clerical than a theorizing task, with emphasis on flexibility of both text and index data bases and their interaction, offering strong support for retaining the complexity and fluidity of “soft” data (Richards, 1993; Richards & Richards, 1991).

GROWING A NUD•IST TREE

Constructing a NUD•IST data base is a two step process: first, deciding how to organize and introduce the data; second, developing a workable node structure. Over the life of a project, decisions about both matters may need to be changed, and the “tree” of nodes needs to remain flexible until the end.

The process of entering transcript data into NUD•IST involves some initial preparation using a word processor to check spelling, remove formatting, break long paragraphs up into appropriate subject “chunks” or “text units” which the program will use. The choice of text-unit is normally between a paragraph and a line, depending upon what is most meaningful for the project. The choice must be made at the stage of saving the document in the word processor: Microsoft Word, for example, offers a choice between “Text Only” (producing units as paragraphs) or “Text Only with Line Breaks” (producing units as lines). Other word processors provide similar choices.

In this project, the interview transcripts were prepared as documents under the names of the interviewees in chronological order of interview (e.g. Alice#1 to Alice#7). Interviews involving two or more speakers were divided into separate documents (by removing all contributions of other speakers). This was done to facilitate the indexing of reference transcripts at “Base Data” nodes (see below).

The line length was set to 60 characters and the documents saved in MS Word as “Text-only with Line Breaks” in order to create single line text units. These files were then placed in the project’s “Rawfiles” folder

and "Introduced" into NUD•IST. The program stores each document as a sequence of numbered "text units":

The example below, from the NUD•IST Docfile Alice#1, consists of seven text units.

```

61   IAN: What are the benefits of computer modelling to an
62   architect?
63
64   ALICE: The only benefit I can think of is it can show us
65   the way how the components disassemble and assemble again.
66   Also, we can store the information like reading a book, you
67   can pick up the information anytime you want to.
```

Figure 5-1: NUD•IST report format

The second stage is to develop a "tree" of nodes at which to index the text units. This can be accomplished either by writing a "command file" or by using the graphic interface which was developed originally for NUD•IST 2.0 on the Macintosh (the current version is 3.0.5 which is cross-platform Windows/Macintosh). Command files are useful to automate repetitive processes, but the graphic "tree" aids visualization of the data base. The structure and content of the nodes as well as the "depth" of the hierarchy is flexible and although the *Handbook* (1994) provides limited general advice on designing index systems, the tree structure is under the full control of the researcher and "can be modified as understanding of the data grows and develops throughout the lifetime of the project" (Richards, 1994 p. 7:2).

In the example below, which represents the first seven nodes of this project, the Command file (a) build-tree creates the graphic tree (b) with three levels of nodes.

(a) Command File

```
(build-tree
  ("Base" ("T-Dau-gung" ("Desmond" "Yin" "Bonita")
    "T-Base" ("Ronald" "Kam" "Alice" "Will")))
```

(b) Resulting tree

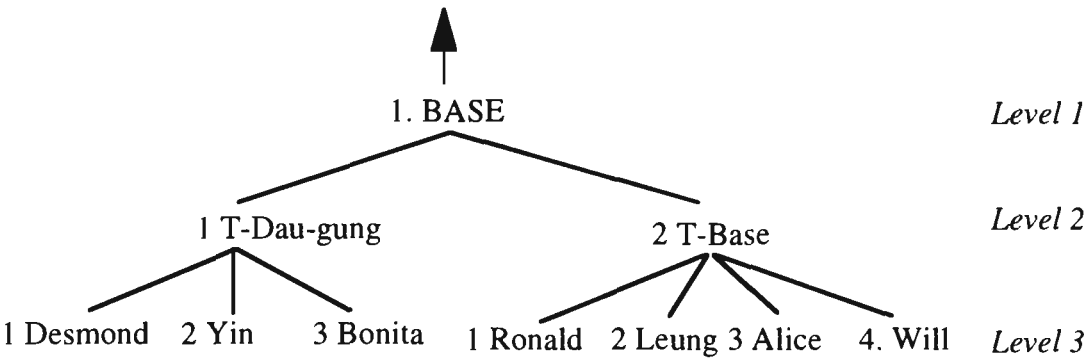


Figure 5-2: Three levels of nodes

STATISTICAL REPORTS

When NUD•IST carries out a search across nodes, it displays statistical information about the number of text units it has retrieved in relationship to the data base as a whole. In the descriptions of the indexing system below, examples are provided of typical text which has been indexed at the node. Following the transcripts are statistical reports generated by NUD•IST which show:

```
+++ the number of text units indexed at the node,
+++ the ratio of documents with indexed units to the total
    number of documents - as a %age
```

The gross *number of text units* is not a significant measure in itself as text units are simply lines of unedited transcript. These include hesitations and repetitions, as well as interviewer questions and blank lines. However, the figures can be used to compare the *relative* amount of data indexed at different nodes and thus the relative importance of the

concept represented by the node. The second measure – the ratio of documents indexed at the node compared to documents as a whole – provides a rough indication of how widespread the indexed concept is in the data. These figures are included for reference under the node descriptions below and tables summarizing the relative weightings of the sub-nodes (both gross text units and %age of documents indexed) are included where relevant.

TEXT UNITS		DOCUMENTS	
Interface	301	Software	23%
Software	225	3D	15%
3D	195	Interface	12%

Table 5-1: example of statistical summary

Table 5-1 is an example of part of a node summary table. It illustrates that the largest number of text units (301) was indexed at the sub-node "Interface", but these text units only occurred in 12% of documents; whereas "Software" which indexes fewer text units was mentioned in twice as many documents.

THE TREE

Figure 5-3 shows the six highest level nodes of the final tree.

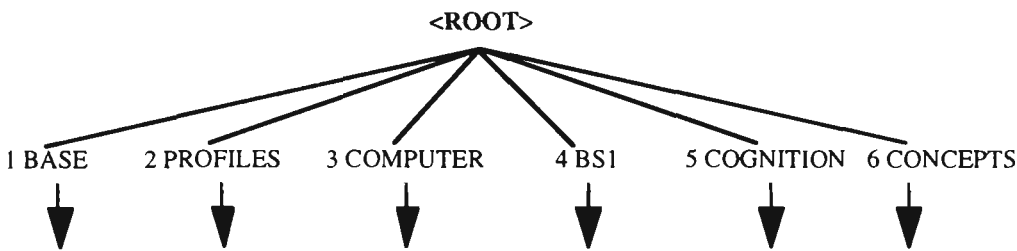


Figure 5-3: NUD•IST tree at Level 1

All data was indexed first at Node 1: BASE. Node 2 provides sub-classifications of the students, produced from some of the student profile

information described in Chapter 4. Node 3 indexes all of the information about entry-level computer knowledge, mainly from Interview#1. In an earlier version of the tree, four interim nodes were developed to meet particular needs of the moment. These have now been removed. Node 4 contains information on the Building Systems 1 course and the four student projects. Node 5 indexes the data according to cognitive issues and Node 6 was created after the last interview as a container for the data from the concept mapping software.

The basis of the indexing and the structure of each node is described below.

BASE DATA NODE 1

The BASE DATA node has 6 Level 2 nodes, representing the five project groups, plus a node for teaching staff, and 25 Level 3 nodes, representing the 19 students and 6 teachers, tutors and technicians. Figure 5-4 shows the student sub-nodes only (the 5 Staff sub-nodes for Barry, Matchy, Waycal, Raymond and John have been left off to save space).

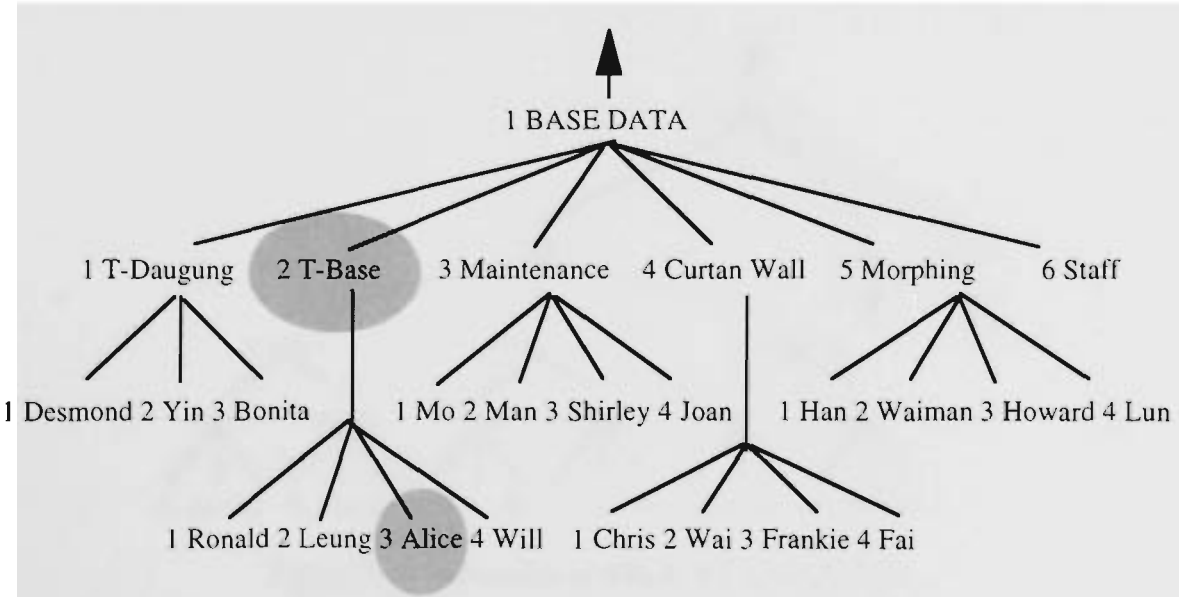


Figure 5-4: Sub-nodes of BASE DATA (1) with Alice indexing highlighted

As a first step, all documents originating from each participant were indexed at their BASE nodes: e.g. all text in all seven “Alice” interviews was indexed at both node (1 2) “T-Base” (Temple-Base, the code name of her project group) and at node (1 2 3) “Alice” as indicated in Figure 5-4.

One reason for the use of Base Data classifications is to facilitate future searching: e.g. an “Intersect” search on the (1 2 3) “Alice” node and the (3 4 1) “Project needs” node would produce everything Alice had to say about computer needs for her project..

PROFILES NODE 2

SPQ RESULTS

The second set of nodes is based on student profiles developed from the Study Process Questionnaire and the Computer Skills test. A third sub-node was added later to index the BS1 and final results. Figure 5-5 illustrates how the SPQ scores were used to index student data.

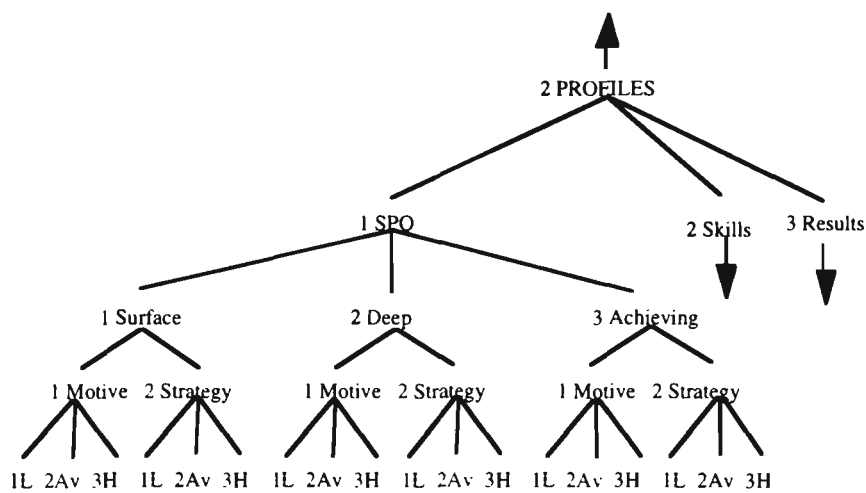


Figure 5-5: Sub-nodes of PROFILES/SPQ (2 1)

Under the SPQ node there are 18 Level 5 nodes representing Low (L), Average (Av) and High (H) scores on Motive and Strategy for each of Surface, Deep and Achieving approaches (explained in Chapter 4).

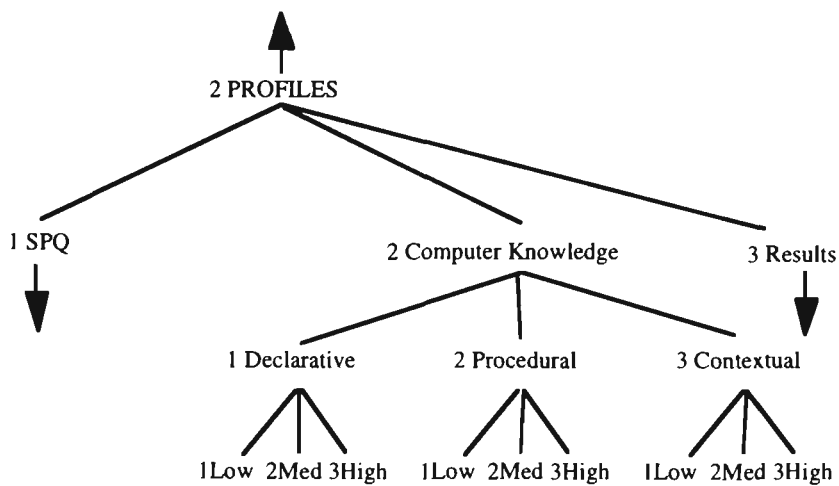


Figure 5-6: Sub-nodes of PROFILES/Computer Knowledge(2 2)

COMPUTING KNOWLEDGE

Under Computer Knowledge there are nine Level 4 nodes representing Low, Medium or High levels of Declarative, Procedural and Contextual computer knowledge (see Chapter 4).

RESULTS

The third sub-node reflects the Department of Architecture’s assessment of each student, using the results for BS1 and the final assessment for the M.Arch.

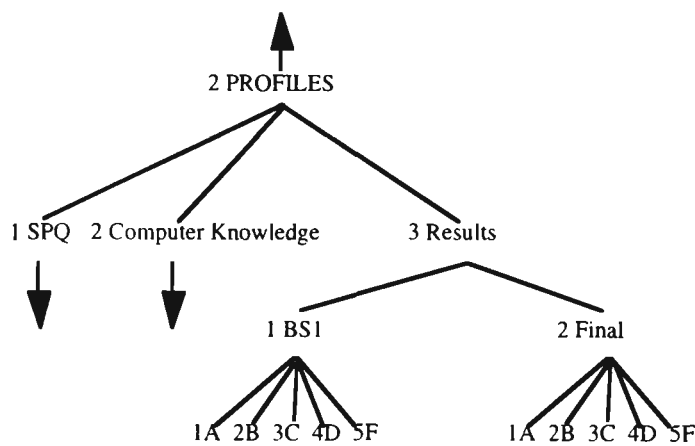


Figure 5-7: Sub-nodes of PROFILES/Results (2 3)

Each student's complete transcripts, therefore, are indexed at eleven PROFILE nodes, representing their SPQ their Computing scores and their results. The indexing of Alice's six interviews is set out as a command file "argument" in Figure 5-8 below.

```
(2 1 1 1 2) SPQ/Surface/Motive/Average
(2 1 1 2 1) SPQ/Surface/Strategy/Low
(2 1 2 1 2) SPQ/Deep/Motive/Average
(2 1 2 2 1) SPQ/Deep/Strategy/Low
(2 1 3 1 1) SPQ/Achieving/Motive/Low
(2 1 3 2 1) SPQ/Achieving/Strategy/Low
(2 2 1 1) Computer/Declarative/Low
(2 2 2 2) Computer/Procedural/Adequate
(2 2 3 1) Computer/Contextual/Low
(2 3 1 3) Results/BS1/C
(2 3 1 2) Results/Final Year/B
```

Figure 5-8: Command file argument for indexing Alice documents at Node 2.

Using the indexing in these first two nodes, it is possible to interrogate the data employing multiple criteria, such as:

- a) Students in the Temple-Base Group, with
- b) Low surface strategy, and
- c) Low computer contextual knowledge, and
- d) Who scored B or better in BS1...

Indexing of the BASE and PROFILE nodes was carried out using command files, based on information about the students obtained from SPQ scores, a computer demonstration and departmental assessment. For developing further nodes a mixture of hypothesis and grounded theory was used.

INTERIM NODES

In the first months of the project a number of interim node structures were developed in order to classify new data which was coming in, to identify issues which were becoming important and to begin testing theories about the data. NUD•IST was also used to structure data for inclusion in papers being written by the Action Research team.

“PROJECT” NODE

This interim node was developed early in the semester to investigate and compare what students were saying about the BS1 course. The results were used to make a first report to the Action Learning team (Will, Bradford, Hart) which could be used for reporting to a general meeting. The Project node comprised sub-nodes for:

Procedures (research, storyboarding, presentation, software choice, division of labour, timetables)

Course (teaching methods, learning, working in groups, resources, assistance)

Problems (system, software, transferring files, losing files, lack of information, coordination, time management)

“ANALYSIS” NODE

In April 1995, the Action Learning Project required an interim report on the evaluation of the program and a node was developed to help organize the relevant information. This was done by interrogating the NUD•IST data base to produce the information for writing the report. The Analysis node had two sub-nodes:

Processes: contained narrative information on current progress of the group projects. It comprised four sub-nodes, one for each project and each of these had seven sub-nodes: Aims, Division of Labour,

Storyboard, Research, Computing, Progress and Product. These became sub-headings in the report.

Problems: this node also contained four project headings at which were indexed the results of NUD•IST “Intersect” searches on BASE/<Project name> and PROJECT/Problems

“LEARNING” NODE

This node was developed in May 1995 to assist the writing of a paper for the First International Cognitive Technology Conference. (Bradford, Hart, & Will, 1995; reprinted in Appendix C). There were four sub-nodes of Learning:

Content: domain and computing,

Skills: procedural, contextual and interpersonal,

Strategies: cognitive complexity and cognitive construction, and

Metacognition: self-knowledge and task knowledge.

These sub-nodes indexed both material from NUD•IST searches and new material from more recent interviews which had been indexed directly at the new nodes.

“COGNITION” NODE

Yet another node was developed to organize a paper for the International Conference on Computers in Education (Hart, 1995a; reprinted in Appendix C) in Singapore. Its sub-nodes were:

Knowledge: declarative, procedural, contextual

Thinking: Cognitive complexity, cognitive construction

Metacognitive: Knowledge, strategies, situated learning

Distributed cognition: Within the group; with the computer

This node also comprised material derived from searches plus new transcripts which had been indexed directly at the new nodes.

By this stage the tree had become unworkable as the new nodes had been developed based on, in some case, searches of searches and newer material had been indexed according to the needs of the moment rather than the long-term needs of the research project. In March 1996 it was decided to re-index the entire project from the beginning. The BASE DATA and PROFILE nodes were retained and refined, the "interim" Project, Analysis, Learning and Cognition nodes were scrapped and four new nodes were developed:

3. **Computing Knowledge**, indexing declarative, procedural and contextual knowledge about computing; dealt with in Chapter 4: Computer Skills
4. **Domain knowledge**, indexing data concerning the pedagogy and organization of the course as well as the progress of the projects
5. **Cognition** which indexes data concerning the cognitive processes involved with learning and computers
6. **Concepts** indexing the final interview centred on the PFnet; discussed in Chapter 4.

COMPUTING KNOWLEDGE NODE 3

INTRODUCTION

Interview#1 involved the students' producing a three-dimensional shape on an SGI computer, using whatever software they thought appropriate, and to talk aloud as they worked. They were also questioned about their preferred ways of working, their preferences for different software and their views on the value of computers in architecture. Demonstrations

lasted on average 15 minutes and concluded when it was obvious that the student had proceeded as far as s/he was capable, or a complex 3D shape had been produced. The demonstrations were video- and audio recorded, using the P-in-P set-up illustrated in Chapter 3.

INDEXING COMPUTING KNOWLEDGE

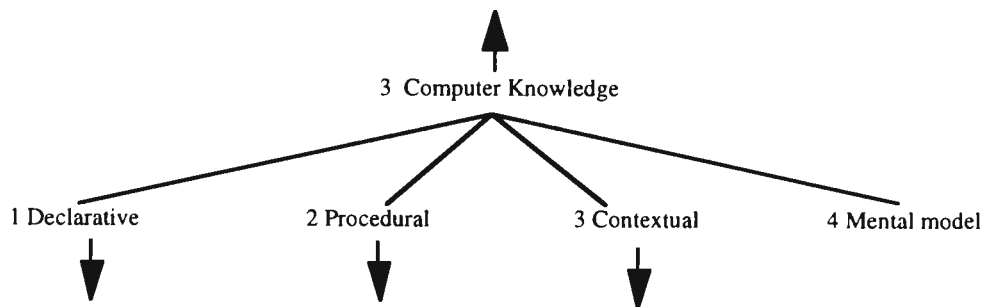


Figure 5-9: Sub-nodes of Computer knowledge (3)

Node 3 was created to index references to knowledge of computing in all possible meanings of the term. (Most of the material indexed comes from Interview#1 when students were demonstrating their computer knowledge, but as the project progressed further transcripts were indexed here also, which accounts for the fact that as many as 27 documents are indexed at some nodes.) The key words and concepts identified were found to divide neatly into Ryle’s (1949) classification of knowledge as Declarative (knowing *that*), and Procedural (knowing *how*) plus Tennyson, Welsh & Christensen’s (1985) category, Contextual knowledge (knowing *why, when* and *where*) and it was decided to adopt this convenient classification.

DECLARATIVE KNOWLEDGE (3 1)

Declarative knowledge was exhibited in both verbal and visual behaviour and was defined as *being aware of and understanding content: facts, concepts, principles and rules and their connections..* Declarative knowledge is the foundation of content and implies knowing *that*. “For

example, the student knows the definition of a given concept and knows the connections of the concept within the domain.” (Tennyson, Elmore, & Snyder, 1992 p.20)

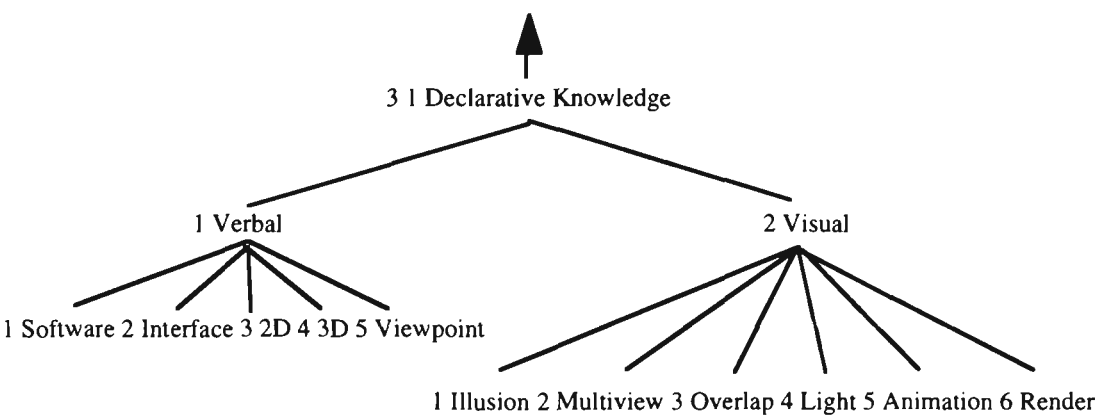


Figure 5-10: Sub-nodes of Cognition/Knowledge/Declarative (3 1)

VERBAL BEHAVIOUR (3 1 1)

Verbal indications of declarative knowledge were extracted using a word-frequency count from the transcripts. Plurals, inflected forms and synonyms were condensed and the meaningful terms listed and classified.

Software (3 1 1 1)

The most basic element of declarative knowledge concerned the appropriate software to use for the task, from the large range available on the server. In particular: **AutoCAD** and **3D Studio** and helper programs like **AME** (Advanced Model Extension), **Photoshop**, **Photostyler**, **Renderstar** and **Microstation**. Students needed to know the meaning of basic commands such as **load** and **save**, **import** and **export**, as well as how to interpret file name descriptors such as **dx****f**, **txt**, **mv**, **rgb**, **jpeg**, and to know when to use extensions such as **editors** and **shapers**. The node indexes all instances of terms relating to names of software and references to file formats.

```
+++ Total number of text units retrieved = 225
+++ Retrievals in 27 out of 115 documents, = 23%.
```


Interface (3 1 1 2)

Early versions of AutoCAD employed a **command-line** entry system similar to **DOS**; more recent versions have incorporated a **Windows/Mac-**like environment with pull-down menus. More practiced users knew the **commands** to type in, only using **pull-down menus** when they had forgotten the syntax for a command. The most common commands mentioned by the students were: "**c**" (close polygon), **draw...**, **shape...**, **define...**, **assign** (thickness, height, depth, size, etc.), **set...**, **close...**, **convert**, **merge**, **cut**, **copy**, **paste**, **clip**. The node indexes terms related to software interface.

```
+++ Total number of text units retrieved = 301
+++ Retrievals in 14 out of 115 documents, = 12%.
```

2D Shapes (3 1 1 3)

The first step to developing a 3D model in AutoCAD involves drawing a basic 2D shape. In order to do this, a user must be familiar with: **lines** and **polylines**, **circles**, **squares**, **rectangles**, **polygons**, **curves**, **triangles** and **ellipses**. These shapes are based on a (horizontal or vertical) **plane**, and possess qualities such as **coordinates**, **radius**, **focus** or **centre**; they can be **regular** or **irregular**, **perpendicular** or **horizontal**; can have a **base**, and an **edge**; or form a **matrix** with several **parameters**. The node indexes terms used in the design of 2-dimensional shapes.

```
+++ Total number of text units retrieved = 85
+++ Retrievals in 12 out of 115 documents, = 10%.
```

3D Shapes (3 1 1 4)

An alternative way to produce the 3-dimensional solids was by using the range of **primitive shapes** available from the AutoCAD menu such as: **sphere**, **box** or **cube**, **donut** or **torus**, **tube**, **tower**, **cylinder**, **cone** and "**free-form**". These 3D shapes differ from 2D shapes in that they have additional properties such as **face**, **thickness**, **cover**, **surface**, **colour** and **texture**; they appear to be **solid**, and possess **depth**, **volume**, **mass** and **footprint**; sections

of them are **visible** or **invisible**; and they are made up of **components**, **segments** and **entities**; defined by **vertices**; and can be viewed as **wire-frames** and/or in **perspective**. . The node indexes terms used in the design of 3-dimensional shapes.

```
+++ Total number of text units retrieved = 195  
+++ Retrievals in 17 out of 115 documents, = 15%.
```

Viewpoint (3 1 1 5)

The AutoCAD interface can be set to display up to four **views** (**multiview**) of the same object or **target** and the user can alter the **viewpoint** by manipulating the **camera angle** and **distance** as well as **zoom in** or **out** on the model, **rotate** it, **render** it and even **animate** it. The node indexes terms used in describing the use of "viewpoint" in AutoCAD and 3D Studio.

```
+++ Total number of text units retrieved = 160  
+++ Retrievals in 9 out of 115 documents, = 7.8%.
```

VISUAL BEHAVIOUR (3 1 2)

According to cognitive theorists, visual information may be represented in memory differently to verbal information. "This implies ... the recognition that certain information is primarily visual. For example, the student is aware that certain geometric shapes represent structural strength while others represent perceptual illusions." (Rasco, Tennyson, & Boutwell, 1975)

In order to classify visual behaviour it was necessary to examine more closely the ways in which students explained what they were doing, and to compare this with the video record to make sure that what they said was consistent with what they did.

The 3D illusion (3 1 2 1)

The most basic element of visual knowledge is the awareness that three dimensional computer models are no more than illusions created in two dimensions on a flat screen. Only with this awareness can one comprehend the modelling process and begin to use the software successfully. The node indexes references to the way in which 3D effects are created on a 2D plane.

MO: Basically, a simple 3D model in AutoCAD can be a number of different components. We can merge them together. In fact, there is no real 3D program in AutoCAD. It is only a model of the object. A model is something like a solid which is not really a solid but built up by a number of faces. Thus, the properties of the solid like mass or density do not exist.

+++ Total number of text units retrieved = 69

+++ Retrievals in 9 out of 115 documents, = 7.8%.

Multiview (3 1 2 2)

In order to build these complex objects, AutoCAD provides an option to display up to four different views of the drawing. Understanding the meaning of these views is a prerequisite for the operation of AutoCAD.

HOWARD: The second step is we should adjust the different views for the objects. Now, we can adjust the four views to different directions. One of them should remain as a 2D plane. These four views are looking at different directions

Christina explains how these four views can simplify and clarify the task as the drawing becomes increasingly complex. This explanation is dependent upon Christina's having a clear perception of what each view represents.

CHRISTINA: Say, assuming that we have a house plan with four planes and we don't know the internal design of the house. So, it would be better to draw it simpler at the beginning. Once you started the drawing, it would become more and more

complicated because it will generate a lot of lines. You can draw the exterior wall first, then you can divide it into different layers according to the thickness of them. After entering the 3D modelling (option in AutoCAD), it will set it into different views like what I have shown you before. Like, 3D, Lvision and top view where top view is the front view. I guess there is one more view called side view. Then you can start to draw it though the Lvision or 3D model frame

+++ Total number of text units retrieved = 41

+++ Retrievals in 6 out of 115 documents, = 5.2%.

Overlapping 2D Shapes (3 1 2 3)

Another example of visual declarative knowledge is the interpretation of overlapping shapes and surfaces. Frankie provides a Hong Kong metaphor *bamboo scaffolding* to explain how the "wire-frame" geometric shape is used as the foundation for the perceptual illusion of three-dimensionality. He then explains how other devices (concepts) such as "face" and "hide" further enhance the illusion.

FRANKIE: You can treat it as a frame. It's a like a frame with some bamboo as the skeleton but hollow inside. This is what we call "wire-frame". OK? So, this is the empty "long". The next command we need to use is the "3D faces". We can create a face for it. Here, this is one of them. I can use the command "hide" which will cover that face now. We can use the same method for the rest of them.

+++ Total number of text units retrieved = 125

+++ Retrievals in 9 out of 115 documents, = 7.8%.

Lighting, Rendering & Animation (3 1 2 4/5/6)

Lighting and rendering (colour and texture) are powerful aspects of the 3D illusion, and will be needed later in the project. These three nodes index declarative knowledge about these qualities.

LEUNG: ... I think 3D is closely related to lighting because it gives you another dimension to look at the object. I would like

to use lighting to define the "z" dimension¹ ... The more the lighting effect, the smaller the "z" dimension would be and it is vice versa.

AutoCAD is not the ideal software for these effects and, generally, it was only the students who were familiar with 3D Studio who were aware of the possibilities here.

MO: It's very easy to do it in 3D Studio. We can assign some lighting effects here. It's not difficult at all. There are quite a lot of options in doing the rendering, let us choose the simplest one to do it. If you remember, the object has open endings in the wire frame plane, however, the default in 3D Studio will close all the polylines and cover the open ends with a face.

The other powerful tool for creating 3D effects is animation, particularly rotation of models. Again, 3D Studio is a more suitable tool than AutoCAD.

JOAN: This 3D (Studio) editor is supposed to allow you to do animation on a building by loading a DXF file in it. ... OK! I know some animation tools here. Maybe we can use a file to show it. Any one of these will do.

+++ Total number of text units retrieved = 129
+++ Retrievals in 14 out of 115 documents, = 12%.

TEXT UNITS		DOCUMENTS	
Interface	301	Software	23%
Software	225	3D	15%
3D	195	Interface	12%
Viewpoint	160	Light,Render	12%
Light, Render	129	2D	10%

¹ In 3D modelling the three dimensions are conventionally designated as: x (width), y (height), z (depth).

Overlap	125	Viewpoint	7.8%
2D	85	Illusion	7.8%
Illusion	69	Overlap	7.8%
Multiview	41	Multiview	5.2%

Table 5-2: Relative weightings of Declarative knowledge sub-nodes

PROCEDURAL KNOWLEDGE (3 2)

Some of the transcripts above are also illustrations of procedural knowledge, which Tenysson, Welsh & Christensen (1985). define as "the cognitive skill of knowing how to use content with newly encountered problems." In this case, the "content" is the interface of the chosen CAD program and the "problem" is designing a 3-dimensional shape.

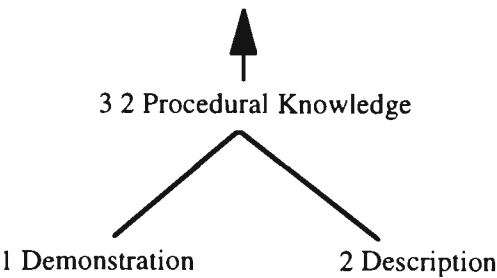


Figure 5-11: Sub-nodes of Cognition/Knowledge/Procedural (3 2)

In the transcript below, Howard, a comparatively skilled AutoCAD user talks us through the process of designing the set of solid shapes shown in Figure 5-12 – an example of a high degree of procedural knowledge. It is clear from Howard's explanation how much the interpretation of the procedure being described is dependent upon his level of visual declarative knowledge and it is apparent that without this knowledge, it would be very difficult to interpret the screen images at all. Howard's transcript below would all be indexed at (3 2 1) Procedural/demonstration. The "Cross-Indexing" column indicates the "declarative" nodes at which these text units are also indexed.

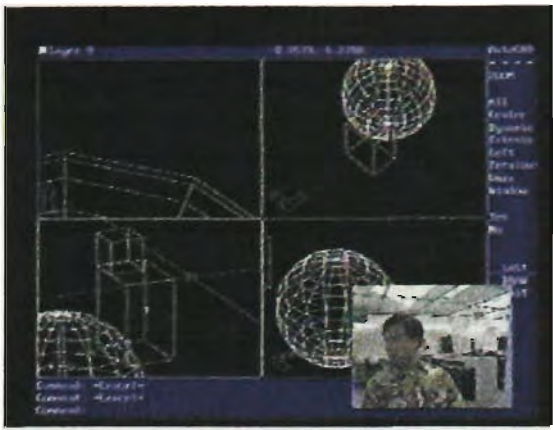


Figure 5-12: Screen capture of Howard and completed 3D demonstration

CROSS-

TRANSCRIPT

INDEXING

Multiview

HOWARD: These four views are looking at different directions. I need to draw some 3D objects on it. So, we can draw a 3D box. We need to enter every single piece of information. The first one we should enter is the corner point of the box. Then, it should be the length, width and the height of the box. I assume these variables are 3, 4 and 5. The next one would be the rotating direction of the box. Say, if I don't rotate it and leave it to zero degree or there is only one section on the screen, you wouldn't know that it is a box then. You need to see it from different directions in order to know that it is a box. Now we can use four views to view it. Perhaps, we can draw one more box. The second box would be placed on top of the original one. I have two rectangles here, and you can also see there are two boxes as well. The reason for us to view it from four different views because for example, we moved this box away, and I retrieved this box back from another view port,say if we have two views only, we might think this box is placed on top of the other. Therefore, it is necessary for us to have more views to locate the problem.

Interface

Illusion

Multiview

2D

Multiview

Overlap

Multiview

DEMONSTRATION OF PROCEDURAL KNOWLEDGE (3 2 1)

Procedural knowledge can be observed in both verbal behaviour and action. The active skill of software manipulation in order to achieve desired results was recorded and analyzed in terms of accuracy of input and/or mouse movements. Students who were confident and accurate in their command-line input and/or use of pull-down menus and who were able to predict the outcome of their actions were judged to have a high level of procedural knowledge; those who made input errors or who had to search through multiple menus to find an appropriate command were judged to have a low level of procedural knowledge. The transcript quoted above is from a student with high procedural knowledge (skills). The way in which students were classified on their “demonstrations of procedural knowledge” was detailed in Chapter 4.

```
+++ Total number of text units retrieved = 981
+++ Retrievals in 25 out of 115 documents, = 22%.
```

DESCRIPTIONS OF PROCEDURAL KNOWLEDGE (3 2 2)

Verbal procedural knowledge was derived from a word count which provided a list of terms that appear to be central to the understanding of the process of 3D modelling. In the table below, the actions displayed in the left hand column are listed in the order from most- to least-commonly mentioned.

ACTION	OBJECT
<i>draw</i>	2D plane, 3D object, face, line, polyline, wire-frame, sphere
<i>view</i>	use command-line or sub-menu commands to set the way the angle and distance at which the object is viewed or to set a multiview (divided screen)
<i>create</i>	2D plane, 3D model, face, sphere, irregular forms, movements
<i>change</i>	colour, dimension, thickness, viewpoint, line, coordinates
<i>command</i> ..	use the command line terms and parameters: e.g. create..., change..., 3D faces..., hide..., model..., dxfout, setview..., dview..., zoom..., etc.
<i>assign</i>	thickness, height, number
<i>build</i>	height

<i>enter</i>	coordinates, size
<i>cover</i>	face, wire-frame
<i>choose</i>	camera, centre, radius
<i>apply</i>	face, functions, rotations, thickness, rendering, media tool
<i>rotate</i>	3D object
<i>define</i>	points, vertices
<i>hide</i>	lines, surfaces
<i>adjust</i>	views
<i>produce</i>	sphere, effect, curved surface
<i>divide</i>	screen
<i>add</i>	lighting, thickness
<i>extrude</i>	shape (from 2D to 3D)
<i>construct</i> ...	complex shapes, models
<i>duplicate</i> ...	shapes

Table 5-3: Key words for procedural knowledge — ranked from most to lease mentioned

+++ Total number of text units retrieved = 278
+++ Retrievals in 29 out of 115 documents, = 25%.

The statistics demonstrate that descriptive terms of procedural knowledge of computers occur in 25% of documents, though they only occupy 278 text units; whereas demonstrations of procedural knowledge (sentences rather than individual words) occupy 921 text units in 22% of documents.

CONTEXTUAL KNOWLEDGE (3 3)

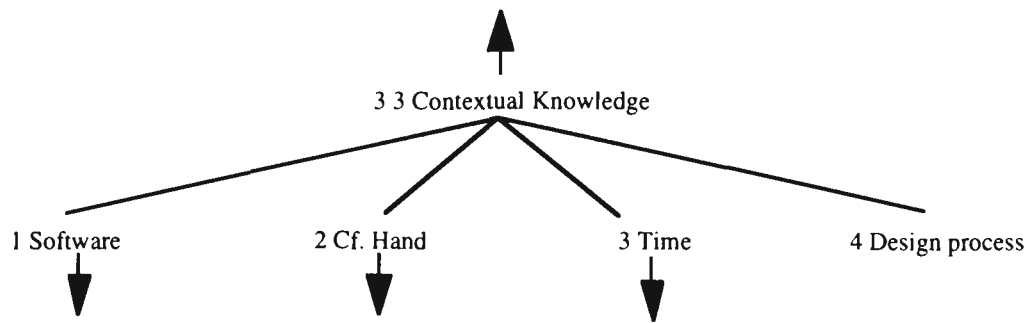


Figure 5-13: Sub-nodes of Cognition/Knowledge/Contextual (3 3)

Contextual knowledge refers to the why, when and where of content and action. For example, the student knows the criteria necessary to select appropriate software to develop a 3D model for use in a computer simulation; or can explain the circumstances in which a computer model is superior to a drawing or scale model. A student with contextual skills is able “to perceive the criteria, values and/or appropriateness of using facts, concepts, rules and principles within complex situations.” [Tennyson, 1985 #202, p.21]. Additionally, contextual skills represent in the student's knowledge-base the rules which govern the connections for the content in the domain. Contextual skills are activated by the cognitive strategies and creative processes when pursuing higher-order cognitive situations.

In the 3D demonstration, contextual knowledge (or lack of it), was most clearly displayed in the “talk-aloud protocol” which accompanied the drawing. The following are some subdivisions of contextual knowledge which were derived from the transcripts:

RELATIONSHIP TO COMPUTER SOFTWARE (3 3 1)

Students expressed a variety of opinions about their relationship with computing, ranging from subjective feelings to opinions about efficiency, accuracy and convenience.

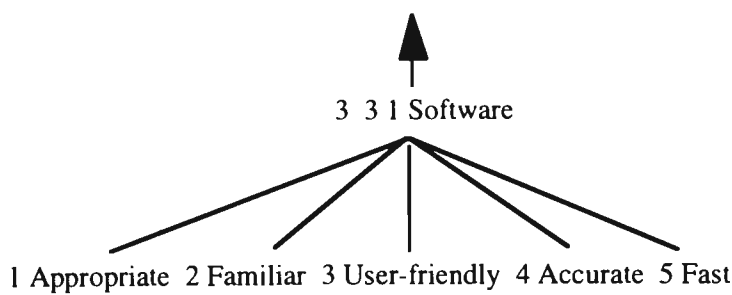


Figure 5-14: Sub-nodes of Cognition/Knowledge/Contextual/Software (3 3 1)

Appropriate software - AutoCAD vs. 3D Studio (3 3 1 1)

AutoCAD, from Autodesk, was one of the first commercially-produced Computer Aided Design programs and it retains its position as the

"workhorse" design program for architectural and other forms of drafting. It dates from the mid 1980s and its first incarnations using a command-line interface were on workstations running UNIX and PCs running DOS; it has recently evolved Windows, X-Windows and Macintosh graphic interfaces which incorporate pull-down menus and WYSIWYG graphics. In spite of these developments, the AutoCAD interface could not be described as "instinctive" and its output is geared towards the printer rather than computer display. The incarnation available in the HKU lab is the X-Windows Version 12.0 running on a SGI workstation.

3D Studio, another Autodesk product, is a more recent development aimed at modelling 3D objects for computer animation and video output. Its interface conforms more to the "instinctive" Mac/Windows standard and the quality of its screen display, particularly of rendered objects, is much superior to AutoCAD.

This node indexed text units which discussed the particular qualities of the software packages.

SHIRLEY: It's very complicated to design something with AutoCAD. I am not quite familiar with 3D Studio, but I know 3D Studio would be faster for you to make a model. You know AutoCAD needs to have all the data for each line or command. However, 3D Studio can take the whole image as input so it might turn out in a faster time. At least it is faster for us to do it.

+++ Total number of text units retrieved = 243

+++ Retrievals in 25 out of 115 documents, = 22%.

Familiarity (3 3 1 2)

All of the Hong Kong students had done a course in AutoCAD several years earlier, although many had not used it since and were now trying to relearn. Only a few students appeared to have operational skills with both software applications.

BONITA: Actually, we needed to use it (CAD) in year 1 and year 2. However, it was not a compulsory subject since then and I didn't take it.... I found that it is quite complicated when I use it. You don't know where it goes wrong. For example, I learned to use version 11 (of AutoCAD), they changed it a little in version 12, but I still need to take about one or two hours for me to relearn the entire system.

+++ Total number of text units retrieved = 256

+++ Retrievals in 30 out of 115 documents, = 26%.

User-friendliness (3 3 1 3)

User-friendliness is a subjective term, but most students believed that 3D Studio was a great deal "friendlier" than AutoCAD. The main difference was that the former used a more "instinctive" interface – you could guess what to do; whereas AutoCAD requires training.

DESMOND: AutoCAD is not user-friendly... it is not like (a Macintosh program) where you can try it out by yourself even though you are novice and be able to create a piece of work without too much problems.

+++ Total number of text units retrieved = 40

+++ Retrievals in 9 out of 115 documents, = 7.8%.

Accuracy, speed & output (3 3 1 4/5)

The two programs have different purposes. AutoCAD provides a high level of accuracy, while 3D Studio's strength is in the speed with which the user can produce and manipulate models. The first two students quoted below are both high-level computer users who have experimented extensively with both programs.

DESMOND: AutoCAD ... is more accurate for me to generate the 2D object. 3D Studio is good at rendering. But I don't think I am going to draw or construct the object through 3D Studio. 3D Studio cannot produce an object accurately. Our *dau-gung* need to be measured precisely.

HOWARD: I normally use AutoCAD to draw the 3D model, then I will use 3D Studio to render it. AutoCAD is a direct tool. If I want to draw a box, it will draw a box for me without any problems. It's more precise to use AutoCAD for the drawing. It knows the locations and the sizes of each point. Also, there are more main points as well. However, AutoCAD hasn't got a good render function.

Christina was not a high-level user but had particular concerns about the output quality of her group's project (Curtain Wall) and had discussed the options with Wai.

CHRISTINA: Yes, but there is a limitation. For example, AutoCAD cannot show you the materials, surfaces and the lighting of the building. The color is not that realistic at all. It is good at showing the object to the viewer from different angles but not the lighting and shading effects. I think the actual object is a little bit unreal.

(3 3 1 4)

+++ Total number of text units retrieved = 50

+++ Retrievals in 10 out of 115 documents, = 8.7%.

(3 3 1 5)

+++ Total number of text units retrieved = 22

+++ Retrievals in 7 out of 115 documents, = 6.1%.

CAD vs. DESIGNING BY HAND (3 3 2)

The ability to draw and draft by hand is a highly valued skill in architecture and some of the more traditional-minded teaching staff are known to have expressed concerns that computers will "de-skill" architects if they come to rely on computers. Some of the students clearly mirror this concern in their interviews and equate computing with the engineering side of the building trade and hand drawing with the "creative discipline" of architecture.

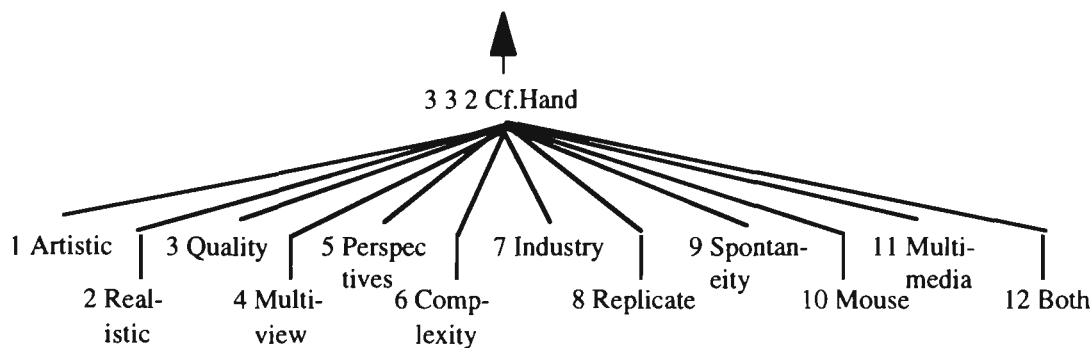


Figure 5-15: Sub-nodes of Cognition/Knowledge/Contextual/CF. Hand (3 3 2)

Artistic qualities (3 3 2 1)

This node indexes comparisons of hand sketching and computer drafting using artistic merit as the yardstick. Alice sees the computer as a somewhat crude and inflexible tool, which forces her to conform to its pre-designed parameters and doesn't provide for more abstract forms of expression:

ALICE: You see in Architecture, we normally draw some solid objects like wall, column and roof etc. However, under the design process, we might think about the space of the entire environment. Obviously, it is difficult to create the space in CAD. On top of the space, we need to create some solid objects around it. So, it would be nice if 3D modeling can create something not only the solid object but also the space as well. Er ... I think the CAD in 3D modeling can help to create something more simple, not too structural, maybe something we can define by some variables. I think it might be difficult for me to create a sculpture if I am an artist.

+++ Total number of text units retrieved = 42
 +++ Retrievals in 5 out of 115 documents, = 4.3%.

Realism and image quality (3 3 2 2/3)

These two nodes index statements about realism ("lifelike") and image quality – both subjective judgments.

LEUNG: I found that the images I draw (by hand) are more lifelike. I can also take more control of the coloring of the picture. The output of the color in the computer depends a lot in the output device from your computer. You need to have very high resolution on your output device, otherwise the color of the object will not be so nice... I think hand-drawn objects are more lifelike

(3 3 2 2)

+++ Total number of text units retrieved = 49
+++ Retrievals in 8 out of 115 documents, = 7.0%.

(3 3 2 3)

+++ Total number of text units retrieved = 48
+++ Retrievals in 8 out of 115 documents, = 7.0%.

Multiple views (3 3 2 4)

One of the perceived strengths of CAD over hand drawing is the ability to investigate an object from multiple viewpoints, whereas a new hand-drawn image needs to be created for every perspective.

FRANKIE: Yes. For example, after you built the object on the screen, you can choose the best perspective for you to view the object. However, hand drawings only allow one view for you - you can't actually say the back of the paper is the back angle of the object. Therefore, the main advantage could be the presentation effect.

+++ Total number of text units retrieved = 61
+++ Retrievals in 8 out of 115 documents, = 7.0%.

Perspectives & complex images (3 3 2 5/6)

These nodes index the ability of a computer to create different perspectives and to convert a plan into an accurate perspective drawing - processes which would otherwise require a considerable amount of calculation and measurement.

MAN: Without a computer we can only guess the perspectives without any measurement. Maybe you can draw it beautifully, but

the measurements are not real and it won't be the same after you built it. (A modelling program) can create the exact perspective for us after we entered some real data into the computer.

But useful as it is, some architects will never be satisfied without their traditional tools:

BONITA: Basically, I will use it to draw the draft of the perspective and then I will print it out and trace the lines again by myself.

(3 3 2 5)

+++ Total number of text units retrieved = 67

+++ Retrievals in 12 out of 115 documents, = 10%.

(3 3 2 6)

+++ Total number of text units retrieved = 37

+++ Retrievals in 7 out of 115 documents, = 6.1%.

Industry standards (3 3 2 7)

AutoCAD is beginning to replace hand-drawn plans in building engineering and the format is quickly becoming an industry standard. This node indexes references to CAD in the city office.

JOAN: Builders use this kind of program to work out the basic plan, and then draw out the building boundary or the rest of the context by hand. By using the computer to draw the building it looks like a "working drawing"... A "working drawing" contains a lot of detailed drawings, but hand drawing is much more free - it can use a lot of colors.

+++ Total number of text units retrieved = 66

+++ Retrievals in 8 out of 115 documents, = 7.0%.

Replication and storage (3 3 2 8)

Saving time and effort by duplicating computer-generated designs was seen as a significant advantage over hand-drawing. This node indexes

references to using the computer to save time through copying and pasting images.

WAIMAN: If the (project) requires many high rise or deep planes, or maybe a lot of repetitive parts, then it would be more convenient to use a computer to do the copying... The advantage of hand drawing is that it is faster, but that for the computer is it can store the data for you and you can retrieve it later when you need it. Hand drawing cannot let you duplicate and change a previous version of the object. In that case, you need to draw it again.

+++ Total number of text units retrieved = 59

+++ Retrievals in 9 out of 115 documents, = 7.8%.

Spontaneity (3 3 2 9)

Indexes statements about whether a computer drawing can be as "spontaneous" as a hand drawing, or needs to be undertaken in a systematic, well-planned fashion.

JOAN: Say if the design work is in the early stage and you want to use the computer to do the sketch of the design, then ... it will be faster if I can use my pen to draw them out.

+++ Total number of text units retrieved = 24

+++ Retrievals in 3 out of 115 documents, = 2.6%.

Mouse vs. pencil (3 3 2 10)

Indexes references to qualities of the input device, particularly the mouse.

LEUNG: I found the geometry of the mouse is not as comfortable as the pen. Architects like to use their pens ... during the design stage. So, they might find it a little difficult to change their environment from the pen to a mouse. I think they need time to get use to it.

+++ Total number of text units retrieved = 16

+++ Retrievals in 2 out of 115 documents, = 1.7%.

Multimedia (3 3 2 11)

Indexes text units which refer to the advantages of presenting material in multimedia format over more conventional static presentation techniques.

WAI: It would be nice if we could have four dimensions which is something we can't show on paper... I think the benefits of using the computer is it can provide four dimensions and multimedia for us. For example the sound and also the organization of information. Also, we can have a lot of windows open on the screen...

+++ Total number of text units retrieved = 27

+++ Retrievals in 2 out of 115 documents, = 1.7%.

Use both methods (3 3 2 12)

Most students see virtue in both hand drawing and computer modelling. It seems that for many students, pencil and paper sketching is a conceptual tool which they use for developing ideas, and they see the computer as a second-stage tool, primarily for presentation. The node indexes statements in which students say there is a place for both methods.

HAN: I will use both methods. I will use the computer drawing if I need to keep changing the objects in a large piece of work. Since it is rather difficult for you to manage a large diagram. What's more, you can zoom the view through the computer. The benefit of hand drawing is you can see the effect of everything immediately. So, it's better for you to do some sketch work first.

+++ Total number of text units retrieved = 47

+++ Retrievals in 8 out of 115 documents, = 7.0%.

TEXT UNITS		DOCUMENTS	
Familiar	256	Familiar	26%
Appropriate	243	Appropriate	22%
Perspectives	67	Perspectives	10%
Industry	66	Accurate	8.7%
Multiview	61	User-friendly	7.8%
Replicate	59	Replicate	7.8%
Accurate	50	Realistic	7%
Realistic	49	Quality	7%
Quality	48	Multiview	7%
Both	47	Industry	7%
Artistic	42	Both	7%
User-friendly	40	Fast	6.1%
Complexity	37	Complexity	6.1%
Multimedia	27	Artistic	4.3%
Spontaneity	24	Spontaneity	2.6%
Fast	22	Mouse/Hand	1.7%
Mouse/Hand	16	Multimedia	1.7%

Table 5-4: Relative weightings of Contextual knowledge sub-nodes

CAD AND TIME (3 3 3)

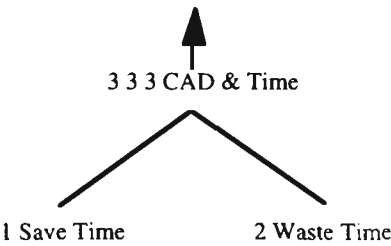


Figure 5-16: Sub-nodes of Cognition/Knowledge/Contextual/Time (3 3 3)

There are obviously situations in which CAD can save a considerable amount of time, particularly the ability to copy and paste information and to duplicate whole sections without having to redraw; on the other hand,

CAD can be an extremely time-consuming process which is not justified by the outcome.

Computers save time... (3 3 3 1)

Indexes opinions about CAD saving time.

FAI: Of course there are some advantages. For example, it could save you a lot of time for you to generate your images. You can copy the objects very easily and build up animation effects without too much problem. It is more easy for you to perceive the animation effects though the manipulation of the computer.

+++ Total number of text units retrieved = 58

+++ Retrievals in 13 out of 115 documents, = 11%.

Computers waste time... (3 3 3 2)

Learning to use a computer program can be frustrating and make demands (for data, procedural knowledge, etc.) which students see as a waste of time, as something they could accomplish much more quickly through conventional means.

WAIMAN: My personal point of view is that it's not a great help because it takes a long time to do anything. If you use that length of time to do just that little part, unless you have a lot of time for your course work, then you can try it out and apply it to your work. Normally, we have time constraints in our course work. We tend to leave the rendering to the end of our assignment.

+++ Total number of text units retrieved = 91

+++ Retrievals in 15 out of 115 documents, = 13%.

CAD AND THE DESIGN PROCESS (3 3 4)

This node indexes answers to the question of where students saw computer-aided design fitting into the overall process of architectural

design. Their answers tended to be highly focused on the concerns of fulfilling course assignments and presenting material for assessment.

ALICE: I think it should be in a later stage. When I am in the design stage I need to think about how to put the blocks in a proper locations... After I've decided that I can then put the structure into CAD, but it would be the time when I need to prepare my assignment. During the thinking process, I wouldn't choose CAD to view the object in different views though.

+++ Total number of text units retrieved = 119
+++ Retrievals in 11 out of 115 documents, = 9.6%.

DOMAIN KNOWLEDGE NODE 4

The Building Systems 1 node indexes all data concerning the teaching of the BS1 unit and the organization of the M. Arch. course (pedagogy); issues surrounding working in groups; the progress of the projects; problems encountered in the semester; and demonstrations of the finished project. This node has been the primary cognitive tool for writing the Case Studies in the next chapter.

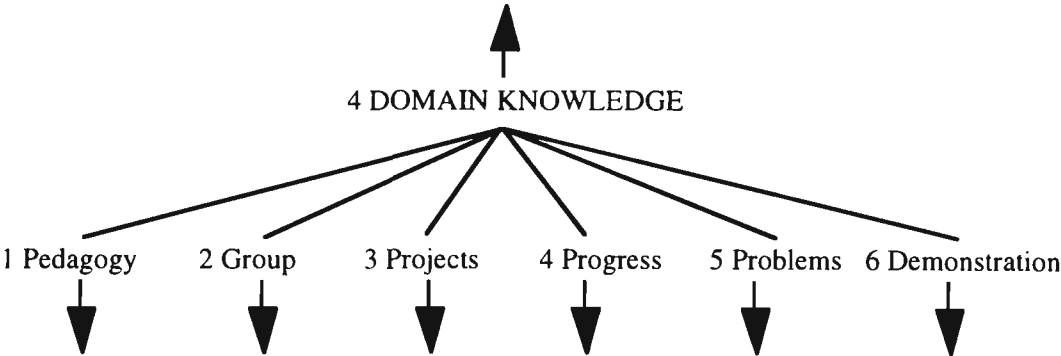


Figure 5-17: Sub-nodes of Domain Knowledge (4)

PEDAGOGY(4 1)

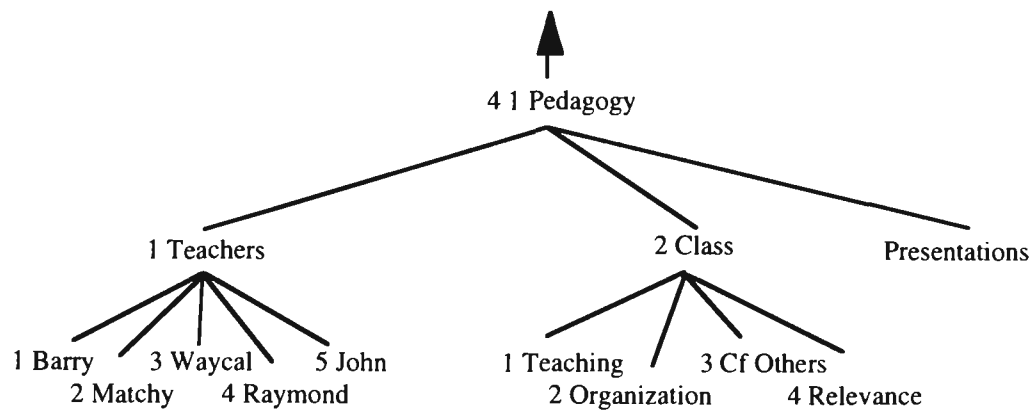


Figure 5-18: Sub-nodes of BS1/Pedagogy (4 1)

TEACHERS (4 1 1)

The “Teachers” node indexes everything said about the teachers, tutors and technical assistants involved with the BS1 course. (Note that it does not index what teachers had to say – these interviews were indexed at the Base Data nodes (1 6 1-6).) This was a topic on which most students had something to say - 25% of documents contain text units indexed here.

LEUNG: I think Barry is like a coordinator. He wants to make sure every project is running according to the right schedule. We have a periodical inspection every week to make sure our progress is under control. This is an important point. He cannot offer us the technical assistance, but he can arrange some research assistants who has this knowledge to help us.

+++ Total number of text units retrieved = 323
+++ Retrievals in 29 out of 115 documents, = 25%.

CLASS (4 1 2)

The Class node indexes issues which arose about the organization and teaching of the course.

Teaching methods (4 1 2 1)

This was the first problem-based course that any of the Hong Kong graduates had done and on the whole they found it challenging but rewarding, and very hard work.

HAN: I think the Building Systems is much like a research work course because in the past we have only ... done it for a short time and done little things. But in Building Systems there is computer work and it is (over) a long period so we should learn a bit more. I think the difference is that we take a more serious attitude to the problem set by the lecturer.

+++ Total number of text units retrieved = 389

+++ Retrievals in 27 out of 115 documents, = 23%.

Organization (4 1 2 2)

The students worked unsupervised for most of the time, coming together for two hours on Friday mornings to report their progress. This node indexes statements about how the time was allocated.

JOAN: On every Friday we have the lecture and everyone has to present what he has done already to Barry Will.

+++ Total number of text units retrieved = 85

+++ Retrievals in 11 out of 115 documents, = 9.6%.

Cf. Other courses (4 1 2 3)

It was not only the problem-based nature of the course which students found unusual, but also the fact that they had to take responsibility for their own learning. Christina takes a fairly extreme position from her perspective as a Canadian graduate, but most students shared her views to some extent.

CHRISTINA: I think in Hong Kong ... most of the courses require you to just memorize. Basically memorization of work, of reading materials. ... They give it to you but don't really ask you to apply it in any ways but just memorize it. If you can memorize it very well, then you do OK. In HK, this is what I

don't really agree with. In terms of learning, you should be able to digest the information they give you and then apply it to something else. Not necessary require you to have a good memory to remember all these materials. It doesn't mean anything after the exams. If you can memorize it and then forget everything.

+++ Total number of text units retrieved = 91

+++ Retrievals in 10 out of 115 documents, = 8.7%.

Vocational relevance (4 1 2 4)

For some students this was an issue: it was important that the course was vocationally relevant to their future as architects; for most, the short-term demands of the M. Arch. course were more important. Note that this node only indexes one document – a group discussion.

HOWARD: It seems interesting, but I'm not really enjoy this because I don't think this sort of study is very useful for my career. My interest is this way - I like to play with computers but actually as study goes I don't greatly enjoy this course.

+++ Total number of text units retrieved = 64

+++ Retrievals in 1 out of 115 documents, = 0.87%.

PRESENTATIONS (4 1 3)

This node indexes comments about the final presentations for the BS1 unit, which most students believed would be the basis of assessment. (In fact this was not the case - the marking scheme gave group work and participation a greater weighting.) For the Temple group, however, there was a "real" client for the presentation – the Chi Lin nuns.

DESMOND: The main way for us to solve it depends on the way how the project should be used. For example, we need to show the detailed structure of the temple to the people outside the university. We need to calculate the exact locations of the model structure and then specify the shape and the size of it. If we are required to present the object in the class only, it

won't take us such a long time to produce this kind of complicated calculation.

+++ Total number of text units retrieved = 33
+++ Retrievals in 4 out of 115 documents, = 3.5%.

TEXT UNITS		DOCUMENTS	
Teaching	389	Teachers	25%
Teachers	323	Teaching	23%
Cf. Others	91	Organization	9.6%
Organization	85	Cf. Others	8.7%
Relevance	64	Presentations	3.5%
Presentations	33	Relevance	0.87%

Table 5-5: Relative weighting of Pedagogy sub-nodes

GROUP (4 2)

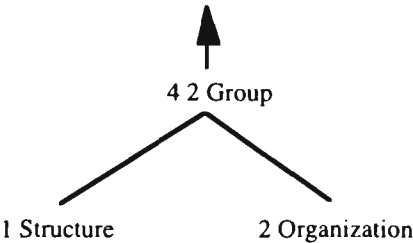


Figure 5-19: Sub-nodes of BS1/Group (4 2)

STRUCTURE OF THE GROUPS (4 2 1)

This node indexes comments about the ways the class was structured into groups.

CHRISTINA: We split up the work into four groups. Each of us did our own work and I think we have our own personal schedule.

+++ Total number of text units retrieved = 60
+++ Retrievals in 11 out of 115 documents, = 9.6%.

ORGANIZATION OF THE GROUP (4 2 2)

This node indexes statements about the internal organization of the four groups.

BONITA: (In the Temple project) there are two (sub-)groups. One group is responsible for the *dau-gung* and the other one is for the roof construction. We compromise with each other for the schedule and then merge all these AutoCAD objects together. Some of us are creating the animation and the others are doing the study. We have a team leader for each group, however, all the members in both groups will have discussion together. You see, it's too much for the leader to handle all the problems of each group member, it would be better for all of us to discuss about them.

+++ Total number of text units retrieved = 300
+++ Retrievals in 33 out of 115 documents, = 29%.

PROJECTS (4 3)

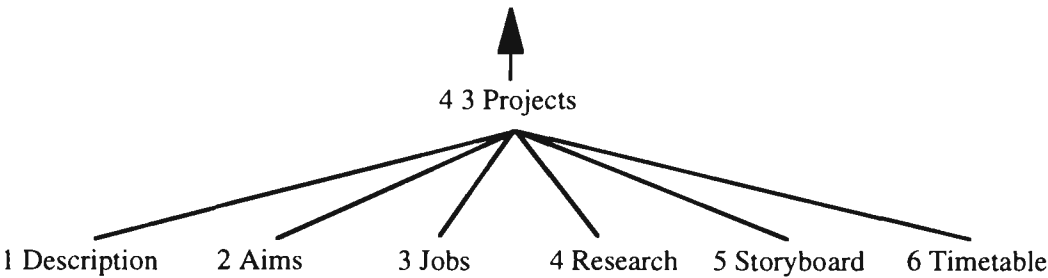


Figure 5-20: Sub-nodes of BS1/Projects (4 3)

DESCRIPTION (4 3 1)

This node indexes spoken and videotaped descriptions of the four projects. Demonstrations were involved in 43 of the interviews. The primary purpose of the node was to be able to compare versions and see how much agreement there was between members of the groups.

MO: OPENING SCREEN OF MAINTENANCE PROJECT. Our group is to propose a Building maintenance program... (break) The program

will talk about the concept and... some other things about the maintenance of a building. It is a real building in Sheung Wan - do you know it? We use a case study which is talking... the introduction is talking now CLICKS ON SCREEN. BOX IN TO FIRST PAGE "INTRODUCTION" - CURRENTLY BLANK WITH SPACE FOR PHOTO

+++ Total number of text units retrieved = 570

+++ Retrievals in 43 out of 115 documents, = 37%.

AIMS (4 3 2)

All of the projects had defined audiences. This node indexes statements about the formal aims, in terms of audience, instructional objectives and anticipated outcomes.

CHRISTINA: I think at first we're aiming at maybe the first or second year of university. Architecture. So they probably won't have much of a curtain wall ... too much training in the technical background of construction, so this would be for them. But really it's for anybody. As for Barry, well at first he intended this to be actually shown to the client of the building so they would be able to understand how everything was put together.

+++ Total number of text units retrieved = 109

+++ Retrievals in 15 out of 115 documents, = 13%.

JOBS (4 3 3)

This node indexes descriptions of jobs which each group member carried out. This was useful when comparing the different working methods of the groups.

DESMOND: (T-Dau-gung) There are four of us in the same group... first we have to understand the *dau-gung* system and then each of us will be responsible for putting the data into the computer.

FRANKIE: (Curtain Wall) Each of us are responsible for two three dimensional CAD drawings and then transform it into 3D Studio to do the rendering and animation. So in this part we

have got all the same kind of work. The second part is the Showcase - Showcase is like a computer magazine We also divided it into four parts. My part is visualizing the working drawings. So, on the screen, one part will show the two dimensional drawing. On the other side will be stuff like this, almost.

+++ Total number of text units retrieved = 330

+++ Retrievals in 41 out of 115 documents, = 36%.

RESEARCH (4 3 4)

Research was an essential component of all the projects. It varied from book research to field work to researching complex computer techniques.

HAN: From the history books. Architecture history. Some of them are by sequence from BC to AD and you can see the pictures and guess and (they) sometimes learn about the structure.

HOWARD: The other group ... researching the way to handle the software to achieve the morphing of the structure. I was responsible for the technology part. In fact, we are still researching the way for us to handle the morphing problem.

CHRISTINA: You have to at least begin with the subject that you are interested in and then do a lot of research on various kinds of topics. And then finally go deep into something non-general... If your research suggested that you should do something else, then you have to do the whole process again. That process is very long and it can take a long time.

+++ Total number of text units retrieved = 149

+++ Retrievals in 18 out of 115 documents, = 16%.

STORYBOARD (4 3 5)

All groups worked from storyboards - a format which architects were familiar with. The storyboards were constantly updated throughout the project and needed to be handed in as part of the assessment. The project storyboards were collected and indexed as off-line documents. (Examples are included in Chapter 6)

FRANKIE: Then we will start another storyboard which will show the whole view of the skeleton and highlight the elements being constructed. This is the growth up part, and this is more general. We start the growth part first. Actually, each of us prepare our own storyboard so that we can have the comparison and then get the best combination out of them. Instead of relying on one person to do the storyboard, our group share the entire work between us.

+++ Total number of text units retrieved = 125
+++ Retrievals in 10 out of 115 documents, = 8.7%.

TIMETABLE (4 3 6)

Time management was an essential part of the exercise - both project management (to ensure it was completed in time) and personal management (to ensure that the work for other units was not neglected.)

ALICE: WE ARE doing the final part at the moment, what I need to do is to draw the support components of the roof and then we can finish the 3D model by putting all the models together from the other group members.... However, I think we need to revise the layout again. We might not have enough time to create the simplified model, so we might need to change the story board a bit.

+++ Total number of text units retrieved = 31
+++ Retrievals in 5 out of 115 documents, = 4.3%.

TEXT UNITS		DOCUMENTS	
Description	570	Description	37%
Jobs	330	Jobs	36%
Research	149	Research	16%
Storyboard	125	Aims	13%
Aims	109	Storyboard	8.7%
Timetable	31	Timetable	4.3%

Table 5-6: Relative weightings of Projects sub-nodes

PROGRESS (4 4)

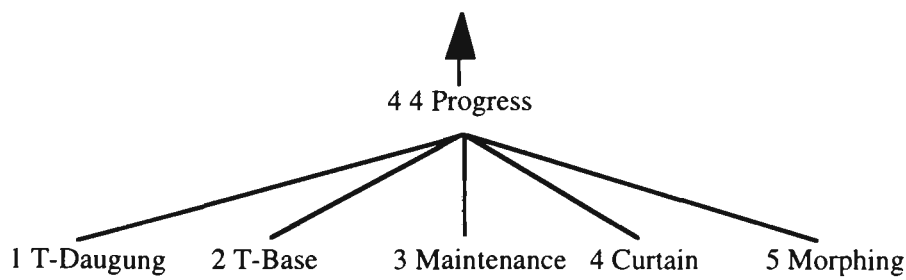


Figure 5-21: Sub-nodes of BS1/Project progress (4 4)

PROGRESS OF GROUP PROJECTS (4 4 1-5)

The purpose of this node was to assist with tracking the development of the projects over the term. It indexes approximately one third of the documents.

DESMOND (Interview #2): (We've done) 3 to 4 percent. This is not really a large part of our project. However, it is a simplified model of our project. After we've done it, we need to create a detailed model but we didn't start it yet.

MO (Interview #4): I think we have finished about fifty or sixty percent. There are some information we have collected already but we haven't linked them up yet. ... (It) is not very satisfactory. We will see whether we can find some better data, otherwise, we will have to keep using the current data.

+++ Total number of text units retrieved = 906
+++ Retrievals in 41 out of 115 documents, = 36%.

PROBLEMS (4 5)

The following nodes were developed early in the project using a data-driven approach, which involved first developing a range of concepts as they arose from the data, then grouping them at nodes. Over time, they were revised and refined into the following nine items:

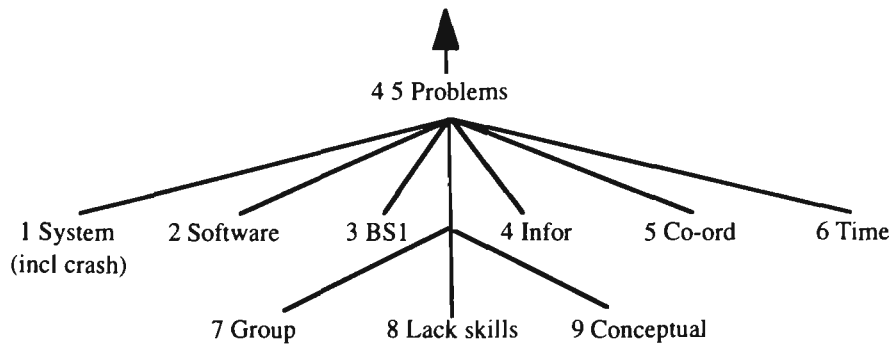


Figure 5-22: Sub-nodes of BS1/Problems (4 5)

SYSTEM (4 5 1)

The computer laboratory contained 16 work stations linked to a server. The student files were kept on a central hard disk, although some students kept backups of individual files on floppy disk. Poor disk management was the cause of many crashes, with students saving multiple copies of large files under different names.

MO: I am not quite sure about the software. I heard people said these workstations are very powerful and fast. However, I don't feel it like that when I use it. It might be because the hard disk is full already. It turns out to be very slow. I have a classmate who created a lot of linkages yesterday, unfortunately, he had a fatal error at the end. It might due to hard disk full up or something else. Eventually, he lost everything he did.

+++ Total number of text units retrieved = 342

+++ Retrievals in 24 out of 115 documents = 21%.

SOFTWARE (4 5 2)

The range of available software (refer Chapter 2) proved to be a problem in itself. A common difficulty which students had was in transferring files between different software, e.g. from AutoCAD to 3D Studio; Inventor to Showcase, etc.

FRANKIE: Sometimes we found that there are some commands which seem quite confusing, we can use different commands to perform the same action. However, there are some commands which used to work but all of a sudden they didn't seem to work anymore.

+++ Total number of text units retrieved = 201

+++ Retrievals in 17 out of 115 documents, = 15%.

THE BS1 COURSE (4 5 3)

This node indexes problems which students experienced with the way the course was organized. In some ways it overlaps with the (4 1) Pedagogy nodes, but the distinction here is that these organizational problems were seen to interfere with project presentation or learning.

JOAN: (If you) do something you don't know you learn it , otherwise you don't have the chance. Maybe if I did the 3D part I would learn how to build a 3D model. But I am doing researching - everybody knows how to do it anyway and just because Mo could handle it (modelling) faster and easier, that was why we give the job to him. Maybe if we could have more time we may organize in a way that everybody would do a job they haven't done before.

+++ Total number of text units retrieved = 48

+++ Retrievals in 5 out of 115 documents, = 4.3%.

LACK OF INFORMATION (4 5 4)

This being a problem-based course, students had to do their own research. There were no text books and no helpful hand-outs from the lecturer. In some cases information was very hard to find. e.g. information on traditional Chinese architecture was not easily obtainable in Hong Kong; information on building maintenance methods was not kept centrally and students had to approach contractors in a range of engineering fields.

YIN: Actually, there is another problem in our project. Since we need to collect the information from the people outside. Sometime we need to wait for them to give us the information or requirements. However, it is not often that we will receive all

the information before the deadline of our project, in that case, we normally would make it up by ourselves. So, this is the most difficult part overall.

+++ Total number of text units retrieved = 125

+++ Retrievals in 11 out of 115 documents, = 9.6%.

COORDINATION (4 5 5)

The M.Arch. timetable is very full, with a range of optional subjects (See timetable in Appendix B). It was often difficult to get all the members of the team together to discuss the project and to work as a team. This node indexes references to problems of coordinating the group.

WILLIAM: Each of us has different program, because we are taking different courses and it's very hard to come together. When someone is free we have to attend lectures or something else... So everyone is doing things at different times. So I don't think this enhances group learning. Like for example someone doing walls, he will just try to finish his work, that's all. And I'm doing the ceiling I will try to finish it in time.

+++ Total number of text units retrieved = 153

+++ Retrievals in 17 out of 115 documents, = 15%.

LACK OF TIME (4 5 6)

This node indexes references to lack of time to complete the project work satisfactorily. The crowded timetable made it difficult to find the time to spend on intensive and detailed computational work. As Christina explains below, this can have an effect on the quality of the product.

CHRISTINA: I spent so much time on it so I'm not gonna change it. I think it happened to a couple of the animations. There's a little part of it wasn't working the way we wanted. I think it was just a mistake, like moving the objects out. And then we were just saying Oh forget it. Because it took so much time to do it and we just decided to leave it that way.

```
+++ Total number of text units retrieved = 99
+++ Retrievals in 12 out of 115 documents, = 10%.
```

GROUP COMPOSITION (4 5 7)

The node indexes references to problems which arose from the composition of the group – personality problems, members not performing to expectation, lack of communication, absences, illness, etc.

MO: There should have been one leader, but I don't think the post of leader had some influence on the outcome because the leader may be me and not... hard to say... for group work I think that most of us are students and we can't put any authority or something else on the other ones. So that if some unhappy things appear I don't know how to solve it and most of the time the work will be shared by the other ones. I don't know how to say this... (Embarrassed to criticize others).

```
+++ Total number of text units retrieved = 58
+++ Retrievals in 7 out of 115 documents, = 6.1%.
```

LACK OF SKILLS (4 5 8)

The node indexes references to and examples of lack of computer skill which interfered with the satisfactory progress of the project work. The quotation in Chapter 4 introducing Mental Models was an example of the confusion which arose from lack of knowledge about the server structure. In the example below Leung lists the difficulties of needing to know so many software formats.

LEUNG: I am more familiar with the PC platform, I found that there are a lot of problems once I transfer the files from Inventor to 3D Studio. There are some faces I thought I have done it, but it wasn't there at the end. I need to go back to AutoCAD and check to see whether there are any parts I have left out. It is like a cycle and I need to go back to the process again and again

```
+++ Total number of text units retrieved = 192
+++ Retrievals in 18 out of 115 documents, = 16%.
```

CONCEPTUAL (4 5 9)

This node indexes instances where students report having conceptual problems with the project, e.g. not understanding how a particular system functions. The highly complex *dau-gung* bracket was the source of great deal of difficulty.

RONALD: I think it is more difficult to create the *dau-gung*. It has a lot of components and the way it assembled is quite complicated. Besides, we haven't received enough pictures of them yet...

+++ Total number of text units retrieved = 65
+++ Retrievals in 8 out of 115 documents, = 7.0%.

TEXT UNITS		DOCUMENTS	
System	343	System	21%
Software	201	Skills	16%
Skills	192	Software	15%
Coordination	153	Coordination	15%
Information	125	Information	9.6%
Time	99	Time	10%
Conceptual	65	Conceptual	7%
Group comp.	58	Group comp.	6.1%
BS1 course	48	BS1 course	4.3%

Table 5-7: Relative weightings of Problems sub-nodes

DEMONSTRATION (4 6)

The nodes here index transcript material from videotaped project demonstrations. The tapes appear in the Rawfiles folder as off-line documents and are not counted in the Reports.

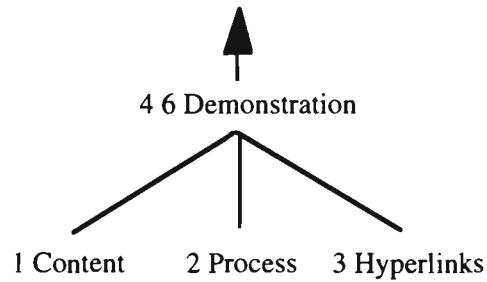


Figure 5-23: Sub-nodes of BS1/Project demonstration (4 6)

CONTENT (4 6 1)

This node indexes transcripts in which students describe the content of their project.

CHRISTINA: This is the building on Connaught Road... I think it is Connaught Road? You know where the Hotel Victoria is? You can't miss it with the colour. (BRINGS UP "COMPONENT" SCREEN) And then this component actually breaks out from the screws to the knobs... and then we go into the... horizontal elements. (CLICKS ON "HORIZONTAL ELEMENTS" BUTTON THEN ON "PRE-CAST U-CHANNEL") Which... I have a picture of it and then, if you want to see an animation of it (BRINGS UP ANIMATION WINDOW TO SHOW COMPONENT ROTATING).

+++ Total number of text units retrieved = 602

+++ Retrievals in 25 out of 115 documents, = 22%.

PROCESS (4 6 2)

This node indexes transcripts in which students describe the process of producing their project and the particular difficulties which had to be overcome. The problem Desmond describes relates to the large scale which was required in order to produce an accurate model of the *dau-gung*.

DESMOND: This one is less complicated. We have another one which has a hole in the middle of the *dau-gung* where we need to put a rod inside so that we can connect one *dau-gung* to another. If you don't put the rod there, then, there are not many points for us to create the hole there. Like the one I

just showed you, it was so small and tiny. Even though we created the hole there, you can't see it. However, we can put it in this one. We need to use this model somewhere else, so we need to emphasize the way how it can be fitted to another part of the model.

+++ Total number of text units retrieved = 262

+++ Retrievals in 15 out of 115 documents, = 13%.

HYPERLINKS (4 6 3)

This node indexes references to the creation of hyperlinks and the structure of the final projects.

MO 00:00:02 to 00:06:46

CLICK ON >> BUTTON: VERTICAL DOORS OUT TO "INTRODUCTION 2" WITH CARTOON IMAGE ON LEFT, TEXT ON RIGHT. "MAINTENANCE MANAGEMENT", "CONCEPT". CLICK ON >> BUTTON: DISSOLVE TO TEXT PAGE WITH INFORMATION ON ROLE OF MAINTENANCE. >> BUTTON: PAGE WITH THREE EMPTY FRAMES "REINFORCED CONCRETE") This picture is not yet ready...

+++ Total number of text units retrieved = 191

+++ Retrievals in 12 out of 115 documents, = 10%.

COGNITION NODE 5

METACOGNITION (5 3)

The sub-nodes of Metacognition index statements which reveal students' thoughts about learning and which demonstrate self-knowledge of their own learning processes.

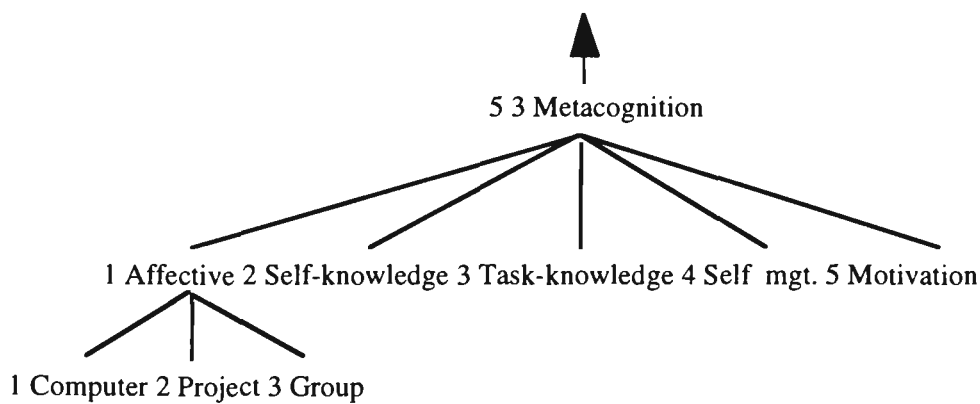


Figure 5-24: Metacognition node (5 3)

AFFECTIVE (5 3 1)

If these students were native speakers they might have used the term “gut feelings” to describe the opinions indexed here. The sentiments are both visceral (in that they are not the product of reasoning) and conscious (therefore metacognitive). The sub-nodes of (5 3 1) indexes statements in which students express feelings about computers, the project work or their classmates which, they believe, affect their capabilities as learners.

Feelings about computing (5 3 1 1)

For some students, particularly those who did not have a great deal of experience with computing prior to this course, computing can be a hostile environment and the why, when and where of computer modelling is affected by feelings of frustration and lack of control. This node indexes comments about liking or disliking working in a computer environment.

ALICE: Normally I will choose not to use it. If I don't have a choice as in the previous year, I have to use it then. Otherwise, I will not choose it.

+++ Total number of text units retrieved = 129
+++ Retrievals in 22 out of 115 documents, = 19%.

Feelings about the worth of the project (5 3 1 2)

This node indexes comments in which students express feelings about whether what they are doing is worthwhile educationally or professionally.

FRANKIE: Well, I agree with her on this point. If we do not do this course work, there is nothing that would drive us to learn this software..... I agree that we need to spend a lot of time in doing these. I just try not to be so negative. I think we can still learn some from the project. Go through the animation allows us to master the

+++ Total number of text units retrieved = 59

+++ Retrievals in 8 out of 115 documents, = 7.0%.

Feelings about the group (5 3 1 3)

This node indexes comments in which students express feelings about working in groups and how this affects their learning.

CHRISTINA: I have also worked on another project this year... Some unfortunately did not work out that well because I think the most important reason was we didn't get along.

+++ Total number of text units retrieved = 17

+++ Retrievals in 4 out of 115 documents, = 3.5%.

SELF-KNOWLEDGE (5 3 2)

This node indexes students' knowledge of their own abilities and the ways in which they prefer to learn: e.g. would you learn to use a computer program by reading the manual or by experimenting or by asking someone to show you? Do you prefer to learn from lectures or from research?

ALICE: I think reading the manuals and books is the best way for us to learn. However, it takes a long time to finish the reading of them. As a result, we normally would turn out ask the other classmates to see whether they know how to do it or not? Once, they taught us some techniques, we start to try it

out. If we have problems again, we will ask people again. Or we will ask the technicians here too....

+++ Total number of text units retrieved = 302

+++ Retrievals in 29 out of 115 documents, = 25%.

TASK-KNOWLEDGE (5 3 3)

This node indexes statements where students talk about their knowledge of the learning task to be undertaken. Many of the text units indexed here would also be indexed at procedural knowledge nodes.

DESMOND: For example this one, you need to draw it in AutoCAD. You need to know how to create 3D object in AutoCAD. Then we need to transfer it from AutoCAD to SGI. It will then involves something in the computer operations. Shouldn't be that difficult. I tend to use PCs more often, so I have some difficulties now. Besides these two systems, we need to use 3D Studio to check whether there are anything wrong in the objects we created in AutoCAD.

+++ Total number of text units retrieved = 432

+++ Retrievals in 41 out of 115 documents, = 36%.

SELF-MANAGEMENT (5 3 4)

This node indexes comments relating to how well the students see themselves achieving learning goals they have set themselves – often the difference between what they say they should do (task knowledge) and whether they follow it through. In the following interview, Christina was explaining how the group managed to cope when Wai, their computer expert, was absent in Beijing for two weeks.

CHRISTINA: I think we did the work quite well. We made some mistakes but there were only a few people around we could ask. (So) we did this and we did that. If (Wai) was around, we could have done it in half of the time. That was the good way to learn because we actually made the mistakes and we knew that. So, we went back and did it. That was a good way to learn it from each other.

+++ Total number of text units retrieved = 236
+++ Retrievals in 33 out of 115 documents, = 29%.

MOTIVATION (5 3 5)

This node indexes statement about motivation to learn. This overlaps indexing under (5 3 1) Affective and also (4 1 2 4) Vocational relevance

WILL: Actually, if I have the chance to build up my own ability in the use of computer, of course it will be an advantage. It's always better to expand our knowledge. So, I will love to.

+++ Total number of text units retrieved = 44
+++ Retrievals in 1 out of 115 documents, = 0.87%.

TEXT UNITS		DOCUMENTS	
Task knowledge	432	Task knowledge	36%
Self knowledge	302	Self management	29%
Self management	236	Self knowledge	25%
Computer	129	Computer	19%
Project	59	Project	7%
Motivation	44	Group	3.5%
Group	17	Motivation	0.9%

Table 5-8: Relative weightings of Metacognition sub-nodes

DISTRIBUTED COGNITION (5 4)

The sub-nodes here index comments relating to the question of the distributed nature of knowledge and thinking. One sub-node indexes "group" knowledge; the other classifies statements about the ways in which the computer undertakes significant cognitive processing on behalf of the user – what Pea (1987, 1992, 1993) calls "distributed intelligence".

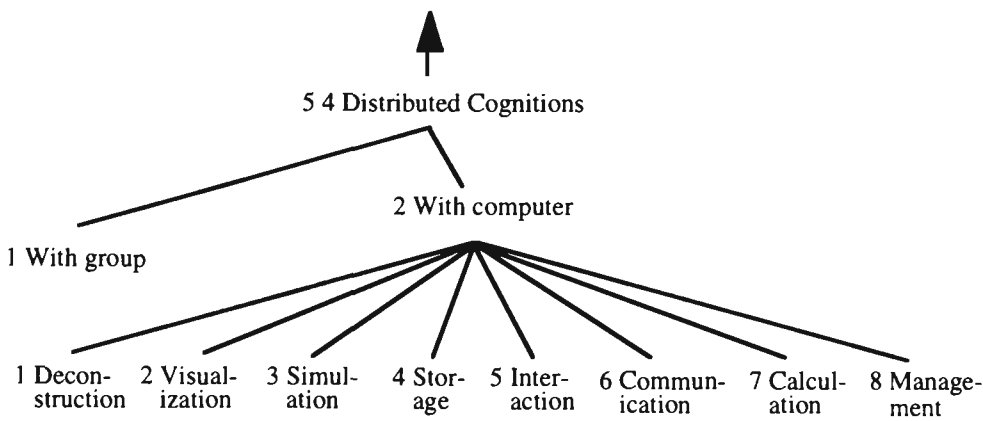


Figure 5-25: Cognition/distributed node (5 4)

DISTRIBUTED WITH THE GROUP (5 4 1)

This node indexes statements about the ways in which both domain knowledge and computer knowledge was shared within the project group.

ALICE: Do you mean group work? Well, I think it has got its advantages. Since everyone can exchange the information they've got. However, we also would have different opinions from each one as well.

+++ Total number of text units retrieved = 304
+++ Retrievals in 25 out of 115 documents, = 22%.

DISTRIBUTED WITH THE COMPUTER (5 4 2)

The sub-nodes below node (5 4 2) cover a range of concepts concerning the computer's ability to undertake cognitive processing on behalf of the student and to share aspects the cognitive load.

Deconstruction (5 4 2 1)

This node indexes statements about computer representation assisting the architect and the client to understand structural issues through being able to deconstruct a 3D model.

LEUNG: It helps us in the presentation so that we can show others how the components are assembled in the system.. The quality of the visualization is far better than hand drawings

even for the people who are not studying Architecture. Even laymen would be able to understand the way the components merge together and then form the building.

+++ Total number of text units retrieved = 50

+++ Retrievals in 9 out of 115 documents, = 7.8%.

Visualization (5 4 2 2)

This node indexes statements about computer representation assisting the architect and the client to visualize a complex structure.

JOAN: If we use the computer in the early stages, we can draft out the block of the building and mainly see the "mass" of the building -- something like building up a toy model -- you can see the "mass" of it after you built it up.

HAN: Yes, but I think it helps the one who sees it rather than the one who does the modeling. For example, when you do the presentation, it's more easy for people to imagine it as a physical model.

+++ Total number of text units retrieved = 322

+++ Retrievals in 42 out of 115 documents, = 37%.

Simulation (5 4 2 3)

This node indexes references to the use of computers to try out ideas and to create simulations.

SHIRLEY: Yes, for example we can use lighting in 3D Studio, so that I can try out different kinds of effects. Also, you might have some material in your mind which might not look the same when you see it (in different lighting conditions). This I found is quite useful.

+++ Total number of text units retrieved = 62

+++ Retrievals in 8 out of 115 documents, = 7.0%.

Storage (5 4 2 4)

The computer can be a substitute for human memory: a means of efficient storage and retrieval of information. This node indexes references to computer as library.

ALICE: Also, we can store the information like reading a book, you can pick up the information anytime you want to. I think the SGI system and the AutoCAD have a good way for us to store and update the information which is better than in the form of paper. Maybe specially for the architecture. For

+++ Total number of text units retrieved = 129

+++ Retrievals in 18 out of 115 documents, = 16%.

Interaction (5 4 2 5)

This node indexes references to the use of advanced interactive computing methods, e.g. virtual reality in order to share ideas with a client or colleague.

LUN: For example, VR ... you can walk into the space and interact with the elements. In the virtual space, you can change the object shape and you can move it. So, it is more possibility for you to design that the virtual space but not what we are doing

+++ Total number of text units retrieved = 75

+++ Retrievals in 9 out of 115 documents, = 7.8%.

Communications (5 4 2 6)

This node indexes references to computing as a communications tool. Christina, below is talking about an exercise she was in called the "Virtual Design Studio" where students at five universities in Hong Kong, North America and Europe sites had shared a design project using the Internet.

CHRISTINA: It's easy to present to other people and easily changed, updated very quickly and doesn't take too long to learn how to use it. Once you change your home pages, you can put them on the net

+++ Total number of text units retrieved = 107
+++ Retrievals in 11 out of 115 documents, = 9.6%.

Calculation (5 4 2 7)

This node indexes references to the computer’s function performing complex calculations (can also be part of simulation and visualization)

DESMOND: We didn't do the calculation directly, we use the computer. For example you can measure many rotation forces. It do it for me.

+++ Total number of text units retrieved = 40
+++ Retrievals in 7 out of 115 documents, = 6.1%.

Management (5 4 2 8)

Indexes references to the computer’s role in distributing the load of project management.

WAI: I think another kind of computer help is the management. If you have so much information, the computer helps you to manage the data, even joins (merging different types of data), it helps you to convert it into different files, different formats. I think the management part is (as important to me as) the physical tools. I think in the future it will take more part in the management roles or even in the tools to help you to create.

+++ Total number of text units retrieved = 22
+++ Retrievals in 4 out of 115 documents, = 3.5%.

TEXT UNITS		DOCUMENTS	
Visualization	322	Visualization	37%
With group	304	With group	22%
Storage	129	Storage	16%
Communication	107	Communication	9.6%
Interaction	75	Deconstruction	7.8%
Simulation	62	Interaction	7.8%
Deconstruction	50	Simulation	7%

Calculation	40	Calculation	6.1%
Management	22	Management	3.5%

Table 5-9: Relative weightings of Distributed cognition sub-nodes

INDEX SEARCHING IN NUD•IST

The bulk of this chapter has been devoted to a description of the NUD•IST indexing system. However, indexing is only the preliminary stage: the purpose of an indexing system is that it can be searched to provide selective information about the data as well as about relationships between the categories. NUD•IST provides many different options for searching the index system:

- *Collation* searches find all text that is indexed at two or more chosen nodes in a certain way, e.g. by all of the nodes, by the first node but not any of the others, or by any of the nodes.
- *Contextual* searches look for text that is indexed by one chosen node that exists in a certain contextual relationship to text indexed by a second node in the document, e.g. preceding it by no more than 5 text units
- *Negation* searches find text which is *not* indexed by a particular node
- *Restriction* searches find index references for a given node in only a certain class of document
- *Tree-structured* searches exploit the hierarchical nature of the data base, e.g. by collecting all the text indexed above or below a given node.

For example, in order to produce the four project case studies in the following chapter, the first step was to separate the data into different

projects so as to ensure that everything said by all the members of the relevant group was indexed at the same node. First, a *Tree-structure* search was performed on the relevant Base Data/Group node in order to merge (union) all of the references in the sub-tree. For example, to collect all the information on the Maintenance group, a *Collect* search was performed on Node (1 3) Maintenance, which has the effect of indexing all the interviews with the group members (below it in the hierarchy) at this single node.

Collation searches were then made in order to obtain specific information from members of particular groups on each topic. For example, to extract text related to **Research** by the **Maintenance** group an *Intersect* search was performed using the nodes (1 3) Maintenance and (4 3 4) Research. This produced 54 text units from 6 documents, and included statements from Joan, Mo, Shirley and Yat-man. Off-line data was also searched in order to provide illustrations, screen captures, storyboards, etc.

The information for each topic was collated and summarized, using relevant quotations from the group members and images wherever possible to add colour and further the narrative.

On p.5:80, it was explained that NUD•IST also provides statistical information on the number and proportion of text units and documents indexed at each node. The statistics are useful indicators of the relative importance which students accord to the issues, and the summary tables at the end of each section ranked the relative weightings of each sub-node according to these sources.

The two indicators provide slightly different information, although in most cases the difference amounts to only one or two ranking steps. The rankings were, however useful in deciding what weight to accord each of the concepts in the chapters which follow.

CONCLUSIONS

This chapter has described the process by which a large amount of unstructured data from 18 months of interviews, demonstrations and observations was indexed in NUD•IST. The initial procedure employed to produce the final tree of nodes was data-driven and owed much to grounded theory, however towards the end, as theories about the data began to emerge, restructuring the tree and re-indexing the data became a recursive process and the final classifications were influenced by the needs of the project. A process of index searching was then carried out to provide the raw material for the following two chapters.

Chapter 6

Learners as designers

Summary: The title of this chapter refers to the student projects which resulted in the design and construction of new knowledge. This comprised both: (a) individual student's insights on the systems which comprise a 1,300 year old Buddhist temple, a contemporary high-rise office tower and a historical survey of roof structures; and (b) the groups' presentations of these insights through the medium of 3D computer graphics. This chapter provides narrative descriptions of the process of this knowledge design from the perspectives of the four project groups.

In the quantitative tradition of education, knowledge is seen as a precious "heirloom" to be passed on reverently from teacher to pupil. The contrary view was well expressed by Perkins (1986) who, in *Knowledge as Design*, described knowledge as actively designed and constructed by the learner. Papert (1990) contrasted *instructionism*, where learners are passive receptacles of media-delivered instruction with *constructionism*, where learners learn by constructing something external and shareable with other learners.

In this study too, the students were not in the mould of what Biggs described as "sponges" soaking up knowledge or empty marble bags to be filled by a teacher (Biggs, 1995). These students were active designers in all senses of the word: both designers of high-tech multimedia environments, and designers of their own learning. This involved them in acquiring and using a wide range of interpersonal, managerial, problem-solving, metacognitive and technical skills. Carver, Lehrer, Connell and Eriksen (1992) in a study of students designing hypermedia environments, list some of the major thinking skills that learners need to use as designers, a list which comes close to an accurate description of the

process followed by the BS class in designing the four projects which follow:

Project Management Skills

- Creating a timeline for the completion of the project.
- Allocating resources and time to different parts of the project.
- Assigning roles to team members.

Research Skills

- Determining the nature of the problem and how research should be organized.
- Posing thoughtful questions about structure, models, cases, values, and roles.
- Searching for information using text, electronic, and pictorial information sources.
- Developing new information with interviews, questionnaires and other survey methods.
- Analyzing and interpreting all the information collected to identify and interpret patterns.

Organization and Representation Skills

- Deciding how to segment and sequence information to make it understandable.
- Deciding how information will be represented (text, pictures, movies, audio, etc.)
- Deciding how the information will be organized (hierarchy, sequence) and how it will be linked.

Presentation Skills

- Mapping the design onto the presentation and implementing the ideas in multimedia.
- Attracting and maintaining the interest of the intended audiences.

Reflection Skills

- Evaluating the program and the process used to create it.
- Revising the design of the program using feedback. (p. 399-400)

CHI LIN TEMPLE

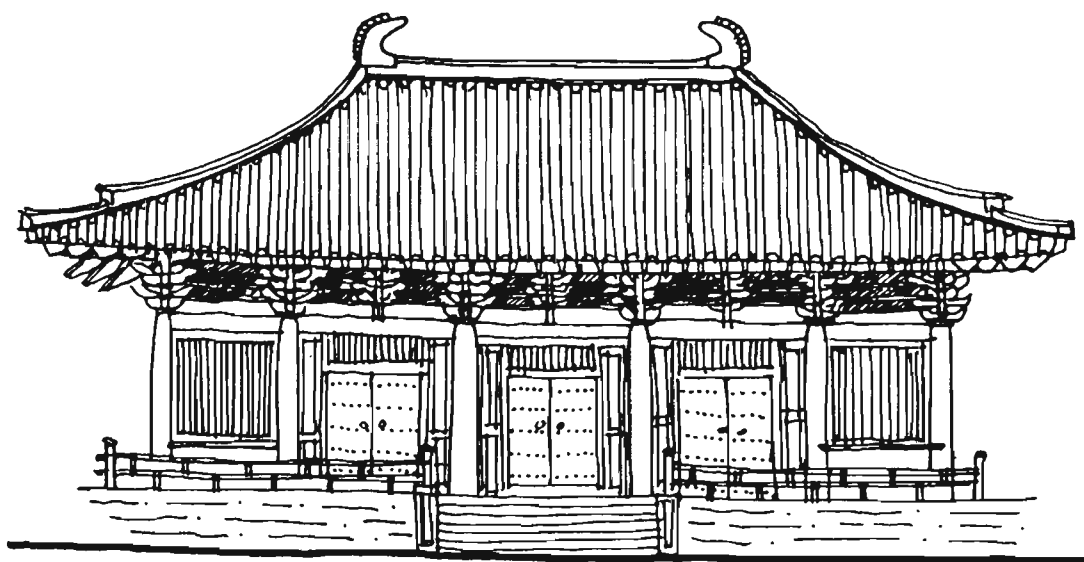


Figure 6-1: 2D sketch of the Temple from the project storyboard

BACKGROUND & AIMS

The Temple Project was a commission from the nuns of Chi Lin Monastery on Lantau Island to create a 3D computer model of a Tang Dynasty (AD 618-907) Buddhist temple which is to be built at Diamond Hill in Kowloon. The design is based on historical temple plans from Shanxi province augmented by Buddhist detailing and ornamentation from Japanese temples which have retained Tang dynasty traditions that have now disappeared in China. The temple architects had provided measured drawings of the temple and the students' task was to develop a three dimensional computer model through which the viewer would be able to "walk" and explore through the use of hyperlinks. The interactive model was to be set up as part of the display in the Diamond Hill monastery Information Centre.

LEUNG: ... this project uses the SGI (Silicon Graphics work station) for visual presentation - making use of advanced computer programs to make a visual dictionary about how the temple is constructed.

The basic temple structure consists of a pedestal on which there are 30 columns each topped by a complex and ornamental *dau-gung* (bracket) the function of which is to support the heavy tiled and curved roof. Walls, doors, and louvre windows enclose the structure. The construction is to be entirely of wood. The students work from measured drawings supplied by the architect.

The project may not appear to be as complex as the modern multi-story curtain walled buildings of the other projects, but because of the level of detail required for the model, the need for research into traditional temples and the intricate workmanship inherent in elements such as the *dau-gung* system, it would prove to be very time-consuming. Another factor is that this project was not simply an academic exercise, but had a "real" client.

DESMOND: ...when we show the detailed structure of the temple to the people outside the university (the clients), we need to calculate the exact locations of the model structure and then specify the shape and the size of it. If we (were) only required to present the object in the class, it wouldn't take us such a long time to produce this kind of complicated calculation

DIVISION OF LABOUR

In recognition of the complexity of the project, eight students were assigned to it, working in two parallel groups. One group focused on the design and development of the *dau-gung* bracket system; the other group was to create 3D models of the remaining temple components – the roof, columns and base. At the end of the term they planned to merge these components into a "walk-through" animation of the complete temple.

YIN: We have eight members in our team. So, we divided it into two groups. One group is responsible for the *dau-gung* and the other one is for the roof construction... They (Temple Base group) are responsible for the views of the building and items

such as the ornamentations... roof, column, wall and staircase etc. When everything is finished within one or two weeks, we can merge all these AutoCAD objects together then do the animation and create different details on each *dau-gung*. The animation we are trying to do is how to disassemble and reassemble the *dau-gung*... We have a team leader for each group, however, all the members in both groups will have discussion together. You see, it's too much for the leader to handle all the problems of each group member, it would be better for all of us to discuss them.

Yin's proposed schedule of "one or two weeks" proved to be excessively optimistic and was not achieved. One of the problems which this project suffered from was lack of coordination and leadership, something whimsically illustrated by this exchange from an early interview:

ALICE: We have a team leader.

RONALD: No, we haven't.

ALICE: Yes, we have.

RONALD: I don't think we have a leader but a coordinator instead. Basically, we divided the team into two groups.

WILL: Yes, we have a coordinator, she is the lady there (Indicating Alice who had just left). Ah, she is not here...

A second problem was the uneven distribution of computing skills between the two groups. The two most competent computer users, Desmond and Yin, were both in the *Dau-gung* group, whereas the Temple Base group included three overseas graduates, William, Ronald and Leung, who had little or no previous experience of AutoCAD.

Both the lack of expertise and poor coordination affected the final outcome of the exercise.

GROUP 1A: BASE, COLUMNS AND ROOF

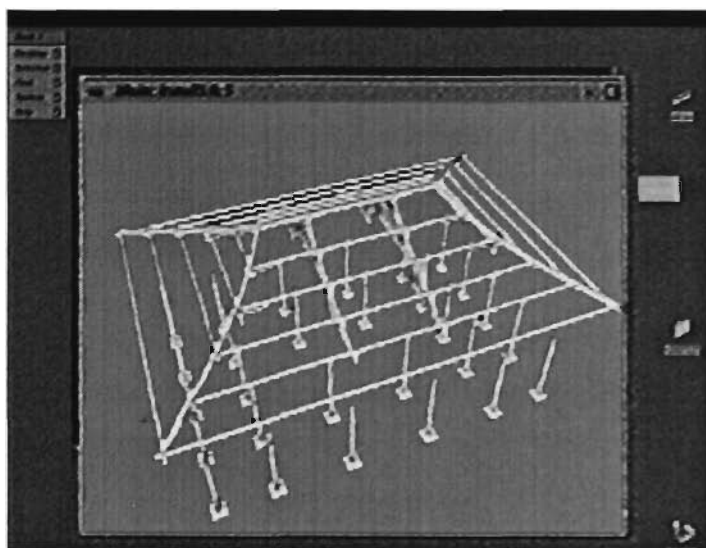


Figure 6-2: Wire-frame image of temple columns and roof

GROUP MEMBERS

Alice: HKU graduate with average AutoCAD skills (not practiced for two years). SPQ score is low on deep and achieving approach and the “Cat’s cradle” PFnet indicates that she was not an enthusiastic computer user. Alice reluctantly took on the role of coordinating this group, but the BSI course was not her first priority.

Ronald: came to Hong Kong from Taiwan where he had obtained a Bachelor of Architectural Studies from Tamkan University. He had done a course in AutoCAD although the SGI environment was unfamiliar to him. Ronald’s SPQ score shows a deep strategy approach, but at times this interfered with his ability to complete work to schedule. Ronald was also having difficulty with some of his other subjects during the term. Nevertheless, he was an enthusiastic and contributing member of the team.

Leung: graduate from the University of London who had worked for over 10 years in architecture firms in Britain and Hong Kong before enrolling in the M.Arch course. A highly motivated student, as demonstrated by his

very high SPQ scores in deep and achieving, however he also has high scores on surface approach, which seems to indicate a student who, having been so long out of the study environment, is unsure of what is required of him. Leung did not have very high computer skills at the beginning of the course, but applied himself throughout the term and became quite skillful by the end.

LEUNG: You know some of our students came from overseas and some of them are Hong Kong University graduates. The graduates of Hong Kong University, are most skillful in using the computer software... those who came from overseas...are not that familiar with AutoCAD or 3D Studio, they need to get familiar with the system first. At the moment, some of the Hong Kong University graduates try to make use of the system first, then they can teach others.

William: (a.k.a. Will) graduated from the University of Malaysia. A highly motivated student, scoring very high on deep approach and achieving motive, but with almost non-existent computer skills. William's particular contribution was in research, having studied traditional Chinese building design in his undergraduate course.

LEUNG: One of our classmates ...(William)... came from Malaysia, he spent a lot of time in studying traditional Chinese architecture. So, he is quite familiar with the background and history. At least his knowledge is better than ours.

DIVISION OF LABOUR – GROUP 1A

The basis of dividing up the work was the perceived competence and preferences of the group members. It was decided that William and Leung would do the background research into traditional temple construction, while Alice and Ronald would begin the input of the 2D plans into AutoCAD. Then, as William and Leung's AutoCAD skills improved with practice, they would be able to take on more of the computing work.

WILL: We try to make everybody comfortable in a way. Those who feel comfortable in doing research, (like me) will go on and do the research... If someone has more experience in doing data input, for example the girl Alice, she is more comfortable in doing data input, she will be more responsible for the data input. This is in the preliminary stage.

The group had weekly meetings at which they compared notes and tried to help one another with computing problems. While each member appeared to be confident about what they were doing, none of them appeared to have a wider perspective on the project as a whole.

RONALD: My task is to draw and assemble all the components together...mainly input the data into the computer...

LEUNG: Yes, I am dealing with the envelope which includes the walls, the doors, the base, the stairs etc.

WILL: I start out from doing the research but I would like to get involved (in creating the models) in a later stage. Therefore, after this (research) it will be my turn (to do the modeling).

But even with the best of intentions, William and Leung were never able to take over the more complex sections of the data input from Alice and Ronald, who continued to carry the bulk of responsibility for the AutoCAD part of the project. Alice, the *de facto* leader of the Temple Base group, devised a system for coordinating the group's work. Nevertheless, keeping all the temple elements together remained a problem until the end:

ALICE: Ronald and I cooperated to do the roof system. The drawing technique is a bit difficult... William is doing the building system. We have to divide the building (between) separate people to draw it. So, we assigned one person to draw a basic frame or basic grid... the rest of us will build up our work on that basic grid. Therefore, the errors are minimized. We can start from that grid and then we can include the parts

we are assigned to. Then we will combine and then proceed and then combine again. It's a series of coordinations.

GROUP 1B: DAU-GUNG (BRACKET)

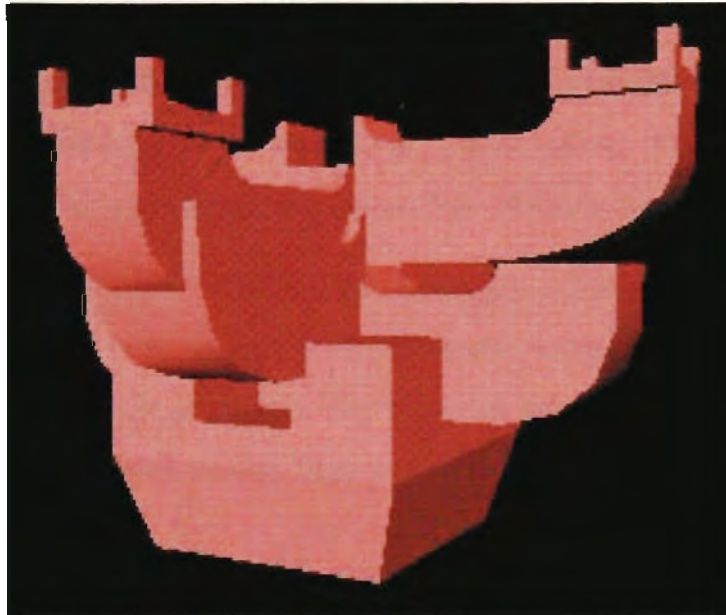


Figure 6-3: 3D model of dau-gung

GROUP MEMBERS

All the Chinese members of this group had known one another since undergraduate days and the overall level of computing skill was significantly higher than in the Temple Base group.

Desmond: a very skillful AutoCAD user with a meticulous approach to design. His SPQ score is extremely low on surface and achieving and in the atypically low range on deep motive. Desmond did most of the detail work on the *dau-gung* design, using his home PC and transferring the files to the SGI system during weekly meetings. (This turned out to be most fortuitous as it meant that after the server crash Desmond had back-ups of all the *dau-gung* models)

Bonita: actively disliked working with computers and had low skills in AutoCAD operation. Her SPQ score is low on surface strategy and

achieving motive, but this is typical of the class. Her main contribution in the group was research on the historical background of the *dau-gung*.

Ho-yin (a.k.a. Yin): The leader of this group. The SPQ shows him to be a deep learner with high achieving strategy - he was a skillful computer user and a highly-motivated member of the group who kept the project on schedule and made sure that Desmond's painstaking AutoCAD work fitted in with Bonita's research and matched Alice's grid plan.

Irene: A Japanese student who worked closely with Bonita on researching the *dau-gung*, which are common in Japanese temples. Irene was not included in the research group as she was not present at the first few classes and left at the end of the first year.

DIVISION OF LABOUR – GROUP 1B

This aspect of the project presented considerable technical and conceptual problems. A *dau-gung* is an interlocking set of wooden components (somewhat akin to a "Chinese puzzle" cube) which is difficult to visualize from the supplied 2D drawings (See Figure 6-6 and Appendix B). There are no examples of these brackets in local Hong Kong temples so it was important for the group to obtain historical information in order to produce realistic and detailed three dimensional models. The computing task, using AutoCAD for data entry and 3D Studio for rendering was complex and time-consuming.

DESMOND:... first we have to understand the *dau-gung* system and then each of us will be responsible for putting the data into the computer. ... The most important part for us is to decide how are we going to manage the shape and curvature of the model in order to reproduce it as the original one.

In order to maintain the work schedule it was important for students in both groups to be self-motivated – working at night and fitting data entry work into spare moments – and to coordinate their efforts closely.

BONITA: Basically, everybody is required to do a certain part of the project. Maybe we can share the same part within our group. It might perhaps be more difficult for the other group (Temple Base group) to share the work. They might however do the CAD model in a group of two or three people. Normally, we will have a certain part (different styles of the dau-gung) to work on anyway.

PROJECT STORYBOARD

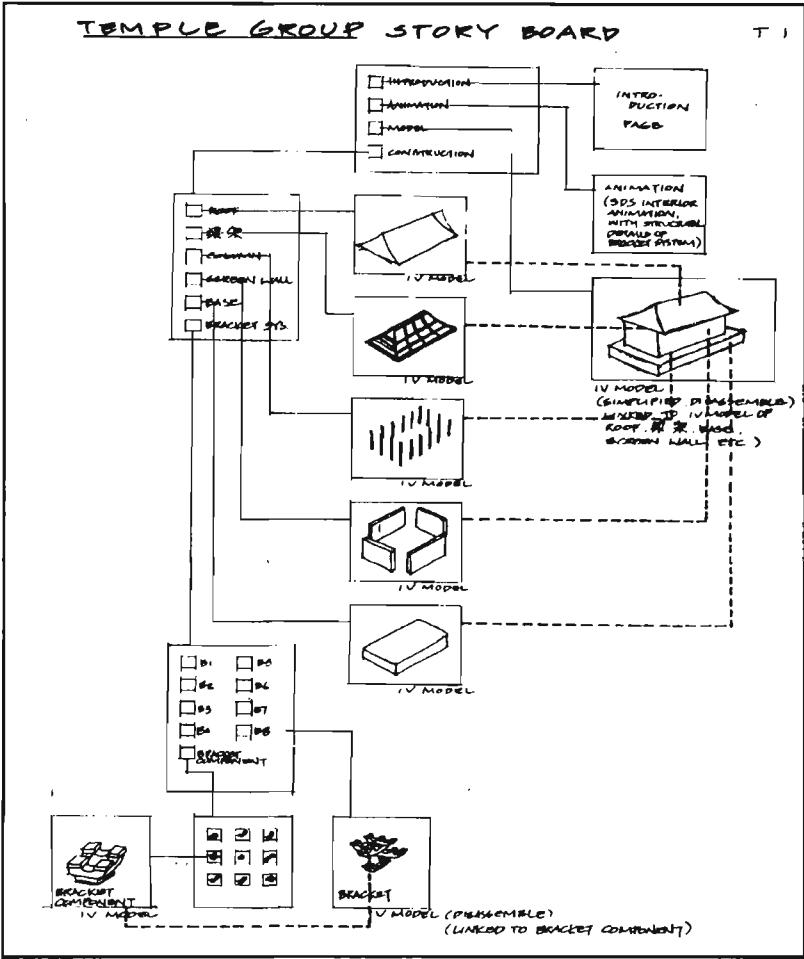


Figure 6-4: Temple project storyboard

The aim of the Temple group was to develop a 3D model of the temple which could be both animated and viewed interactively with hyper-links to the visual dictionary. The storyboard illustrates the user's access to the model and shows the elements which needed to be produced

by the members of the group. The Temple Base group's responsibility was to look after the macro view of the temple – the top 3/4 of the storyboard.

ALICE: I think the major part of the project is to use the computer to create the image of the object. We don't really need to design anything new but just need to think about the storyboard.

LEUNG: I am now working on the storyboard... I try to work out the steps and procedure so that we will know how to present the ideas

The *Dau-gung* group took a more micro-level perspective, concentrating on the structure and detailing of the brackets, which the user would be able to examine in detail and deconstruct. The interlocking bracket system is extremely complex and no two brackets of the thirty are the same (though some are mirror images). The project, therefore, required a great deal of background study as well as detailed analysis of the 2D drawings.

YIN: Just 2D drawings, like plan, elevation and section (were provided). Then we guessed how the components assembled together.

DESMOND:You see the design of these (*dau-gung*) curvatures are based on the way they interlock with one to another. We didn't make it up by ourselves.

The group needed to model the structure of the complete assembly by breaking it down into its individual components – often as many as 10 – and a colour coding system had to be devised.

YIN: This is one of the *dau-gung* in the *dau-gung* system. You see all these different colors are the different components of the *dau-gung*. We use different colors and layers to display them. This is the 3D view of one of the *dau-gung* in the temple. There are about thirty *dau-gung* altogether in the temple and each one of them is entirely different to the others.



Figure 6-5: Bonita and Yin with preliminary detailed model of a corner dau-gung

RESEARCH & ANALYSIS

HISTORY

The temple is a model of a Tang Dynasty temple from Shanxi province. None of the Hong Kong students had any experience with Buddhist architecture as the temples in Hong Kong are of different periods and regional styles, and most of the Buddhist traditions of the Tang Dynasty no longer exist in China, having been replaced by Taoism. However Tang Dynasty influences in architecture, art and music can still be seen in Japan. So a great deal of background research needed to be undertaken before they could begin work.

LEUNG: For myself, I came from overseas, I didn't have too much chance to study Chinese architecture...To me, this is really complicated.

It was necessary to research the temple from the perspectives of architectural design, structure and materials and historical styles. The detailed working drawings from the architects required considerable analysis in order to turn them into 3D models; the structural properties of wood were unfamiliar to Hong Kong students more accustomed to steel and concrete; and it was necessary to understand the historical and

religious context of the building's style in order to make sense of many of the components.

LEUNG: We are carrying out some studies on the ornaments in the temples because you can see this is just a very simple structure model...So we need to study some of the sources and the meanings behind the ornaments and carvings...and the decorations...

William, who had previously studied Chinese traditional architecture as part of his undergraduate degree from Malaysia took on the task of researching the historical aspects of the project. He found material in journal articles and also looked at the work of previous students who had produced the "Temple Tutor", a 3D computer model of a temple near the university which contained hyperlinks to information about Tang and Sung dynasty building styles.¹

WILL: We read magazines or study those work people have done before. ... (However) in the Tang dynasty, they had many styles. Some things were still the same, the frames were still the frames but the styles were different from those in the Sung dynasty, Tang dynasty or Yuan dynasty. We tried to compare those in the Tang dynasty and produced a comparative appraisal to it. I think this might explain the reason why the Buddhist nun wants to choose the Tang style temple for the headquarters.

STRUCTURE

Leung was put in charge of coordination with the project clients, which involved him travelling out to the Lantau Island monastery to discuss the project with the nuns as well as meeting the architects who had supplied the measured drawings.

¹ The main Chinese dynasties: Xia (21c-16c BC), Shang (16c-1066 BC), Zhou (1066-221 BC), Qin (771-206 BC), Han (206BC-220AD), Three Kingdoms (220-280), Sixteen Kingdoms (265-581), Sui (581-618), **Tang (618-907)**, Song (960-1279), Yuan (1279-1368), Ming (1368-1664), Qing (1664-1911), Republic of China (1912-1949), P.R.C. (1949-)

LEUNG: The architect has already designed the temple and he has prepared all the necessary working drawings. I've got the telephone number of one of the architects and I have to make contact with because I am responsible for the appraisal part. I have to understand if there are any reasons behind showing that sort of style, (I have) to understand what's going on with the drawings - for example, the actual dimensions of the members (beams) and how the structure of the temple is formed.

Architecture students in 1995 are unused to working with wooden structures. The practical work of converting the 2D drawings into 3D models involved considerable research into the properties of wood, the functions of the structural components, and how they all fitted together.

ALICE: The temple is not a usual building, it is made up of timber components, of wood. It's a bit different from the building systems we are used to. For our group, we are trying to understand how the roof system works in terms of its components and how to draw it. We will try to understand the details and then draw it because the original drawing was composed (as a) 2D diagram, so we need to draw the 3D version for it.

DAU-GUNG

The *dau-gung* is a traditional bracket system which supports the roof in Chinese Buddhist temples of this period. It consists of a number of carved, interlocking components and the complexity of its structure is not easy for viewers to comprehend. The visualization of the component parts of the *dau-gung* as a 3D deconstruction was to be a central element of the project. The only way that the students could make sense of it was to enter the detailed drawings into AutoCAD and compare the result with models they had found in their research. A detail (about 15%) of the specifications for a single *dau-gung* is shown in Figure 6-6

YIN: The most important part at the moment is to enter all the AutoCAD drawings. Although some of us are working on the

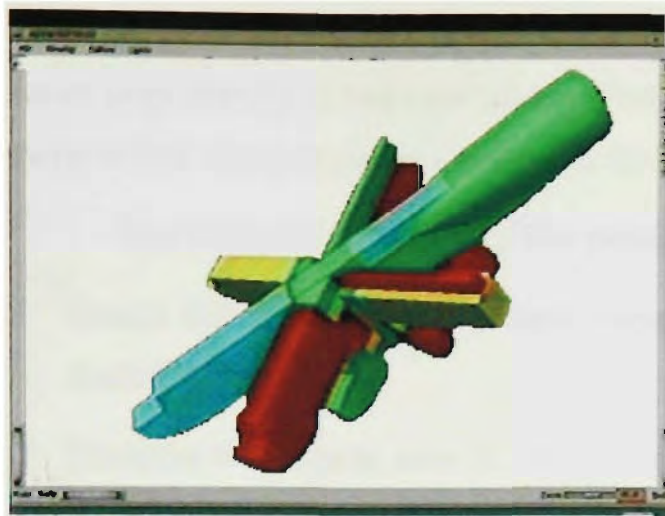


Figure 6-7: Computer model of dau-gung - assembled

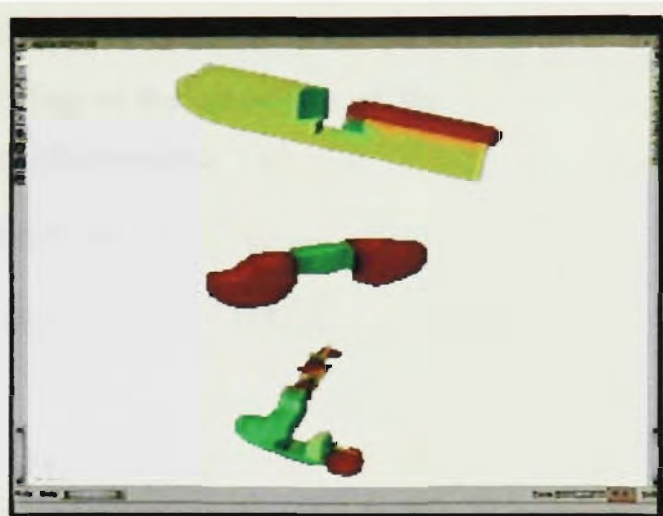


Figure 6-8: Computer model of dau-gung deconstructed

YIN: I think accuracy is important.

DESMOND: Yes, that's right (but) if we needed to go to such a detailed design on every one of them (*dau-gung*), it would be too complicated for the program to handle its size. Perhaps it will be enough to create one or two detailed components. We can't go to too much detail for the entire temple.

A previous student project ("Temple Tutor") also contained several *dau-gung* models:

IAN: Before you started this project did you look at the Temple Tutor data base that already exists? There are similar brackets in it. Did you base anything on it? Did you use that data base at all?

BONITA: No, they're not the same at all.

It was not possible to make use of this material as the brackets employed in these temples were from different historical periods (Song and Yuan in addition to Tang) as well as different regional styles.

COMPUTING

The Building Systems course makes great demands on students' computing abilities. It requires students to develop skills in basic software packages such as AutoCAD and 3D Studio as well as developing a working

knowledge of animation, presentation and hypermedia software; and most importantly it requires an understanding of the structure of the networked computing environment in the Multimedia Lab.

The computing aspect of the project fell into four stages:

- 1 Create the 3D models of temple components from 2D drawings using AutoCAD;
- 2 Transfer the objects into 3D Studio for rendering;
- 3 Combine the separate objects into a single model;
- 4 Create the animation for the "walk through", the hyper-links and the deconstruction of the temple components and *dau-gung* using software such as Anime, CViewer and Inventor

At the beginning of the term, three of the seven students had had very limited computing experience (William, Leung and Bonita), Alice and Ronald were familiar only with AutoCAD but only Desmond and Yin could be described as having high level skills and familiarity with a variety of software programs.

WILL: The modeling, 3D Studio and rendering - you know, we need to use these techniques to reproduce the repetitive components of the model... At the beginning, it was more difficult for me. I needed to learn how to draw the model in AutoCAD. After entering the data and figures into the software, things started getting better. Then, I needed to use 3D Studio for the model. Therefore, I had to learn how to operate it too.

Even for Desmond, an experienced computer user, the task sometimes seemed very demanding:

DESMOND: For example this one, you need to draw it in AutoCAD. You need to know how to create a 3D object in AutoCAD. Then we need to transfer it from AutoCAD to SGI. It shouldn't be that difficult, but I tend to use PCs more often, so I have some difficulties now (with SGI). Besides these two systems, we need

to use 3D Studio to check whether there are any things wrong in the objects we created in AutoCAD.

With eight people working on one project a major concern was accuracy and scale, as the various components needed to fit together perfectly at the end of the process:

WILL: You need to have a lot of coordination. You see, for things like the beams and *dau-gung* you need to have the exact positions of them. They have to be in the right place. The building will work only if you put them all together. A Chinese building is a very fine product - the connections and frames and everything need to be in the exact location and position... We are worrying that the dimensions of different components in our project might not match. Say, each bracket must match one another. If they match each other, it would be much easier to render it through 3D Studio.

The second coordination question concerned the transfer of files between operating systems and between software: PC to SGI, AutoCAD to 3D Studio and then into animation and presentation formats:

LEUNG: First of all, we have to understand the system of the structure of the roof. After that, we need to make use of the AutoCAD software, we can then try to build some 3D models by using the 3D commands in AutoCAD. After that, we'll transfer the 3D files to 3D Studio. At that moment, we'll create a three dimensional model in the 3D Studio program. Afterwards, we will transfer the 3D files to the SGI Inventor to do the rendering and animation through there.

YIN: We need to construct the timber walls of the temple at the end with animation so that the user can walk through the image and view it. We also need to analyze its structure in order to understand the way that the components fit together. Starting from the frame of the roof, to the *dau-gung* and then the columns follow. We need to know the entire process of forming the temple. This is actually a simplified model of the *dau-*

gung, we have some other ornamentations which need to be created. Those decorations are placed in another file because it takes too much memory to place them in the same file.

As the various components were completed and incorporated into the model, problems arose with coordination between the groups and with locating files needed to do animations and presentation. These software packages needed to be operated in tandem within the SGI system and files transferred from one software to another at different stages of the process for rendering, animation and presentation:

LEUNG: The way to design the animation is a bit complicated too. Since the *dau-gung* is too complex, more members are doing that part. Therefore, the rest of the project is not ready yet...we still cannot run the full animation of the model.

ALICE: At first we tried to do the animation for the model and we found that some problems occurred when we tried to disassemble the model. Then we realized that the problem (was because) we couldn't do the Insert command when we were in the model... What we are going to do is to divide the model into more layers so that we can do the Insert function.

DESMOND: The most important part is not the skill of using the application but the knowledge of to transfer the files from one (software) to another.

PROGRESS

The original plan of action was straight-forward and at the beginning of term the group was clear on its direction and time-scale:

RONALD: What we are doing at the moment are the tasks we assigned to each person at the (first) meeting. .. We first will build up the base of it, then the staircase, fence, *dau-gung*, the curved surface of the roof and the ornamentation... we need to build the ceiling and the wall too. These are what we are going to build in the next stage.

TEMPLE BASE GROUP

Within the Temple Base group the work progressed fairly much as planned with Alice and Ronald working on the roof, Will and Leung producing the pedestal, columns and "envelope". However, the complexity of the project with its myriad small components was becoming a problem. Much work was done at night or in moments of spare time and the logging, identification and storage of multiple files on the server became an issue.

LEUNG: I am responsible for the envelope of the temple - the wall, door, louver, base and staircase etc. Since all these are very big, I break down the base as into individual objects. There are quite a few types of doors, so each one of them I put into a separate Inventor files. I have done most of the AutoCAD files and transferred them to 3D Studio already. The faces of these objects have been covered too... After viewing them, I found that there were some problems with the files. Some of them now haven't got a complete face any more... I think I should check the original file to see what is wrong..

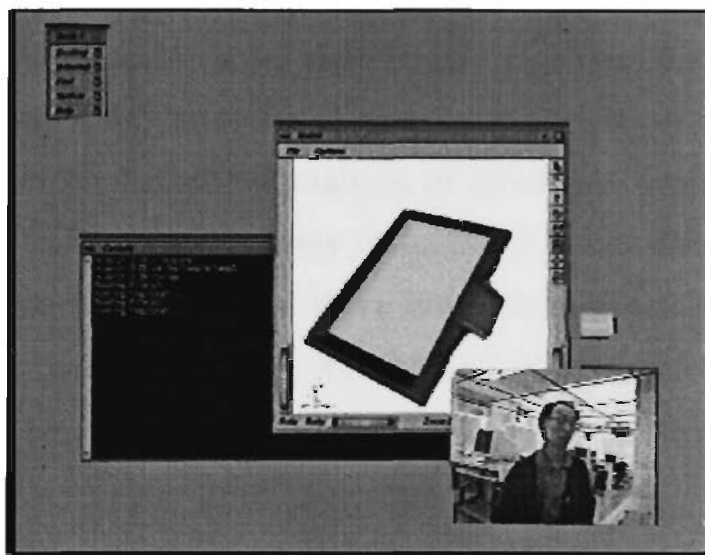


Figure 6-9: Leung is responsible for the pedestal and steps

RONALD: Once we have finished our own parts, we will put them into the group file. Then we can think about how to construct

all these different parts together in order to form the model of the object.

ALICE: We haven't discussed how to present the information in Showcase yet

DAU-GUNG GROUP

The *Dau-gung* group worked independently from the Temple Base group for most of the time, researching and analyzing these complicated structures. At the beginning they needed to use trial-and-error in order to decide on a means of representing the structure and establishing ways of standardizing the working style within the group.

DESMOND: What I am doing now is to see how can we create this part and then apply the whole idea into the project. You see, we are trying out which is the best way for us to group the components of the model together. We have some problems at the moment. After we've solved all these problems, we can then tell the rest of the group members which way to draw the elements. Say, which is the best way for them to assign the grouping or layers.

The next stage was to enter the 2D drawings supplied by the architects into AutoCAD in order to develop preliminary models of the brackets. This involved detailed analysis of all of the components as well as some detective work on how they fit together. It was decided that there was only sufficient time to model three brackets in detail with full curvature and animation to show the method of assembly and deconstruction. All of the other brackets would be simplified shapes.

DESMOND: This is a simplified *dau-gung*. Certain parts are designed in more details and we tend to follow the same features of the original one. As you see this one, we have created an inner part here therefore we can construct another component onto it. We need to design three *dau-gung*. After that, we can construct all of them together at the end.

Designing the roof support brackets required that students have a very clear concept of the structure of the entire temple and the interrelationship between all of its elements. It also required that the two groups coordinate their design information closely if the bracket was going to match with the roof structure.

DESMOND: This *dau-gung* is the bottom part of the roof. We have a column underneath. Then, there is a base below the columns as well. Those are much more easy for us to create. However, there are some rods on the roof where they will form a triangle over there. Like a pitched roof. The other group is working on it now.

COORDINATION

The Temple group's problems with coordination became more serious as the complexity of the project increased. In addition, the problems with modelling the curved roof and fitting it to the *dau-gung* brackets threatened to delay the completion of the project.

LEUNG: Yes. We are still working on it because the group working on the bracket system haven't finished a completed bracket yet. Therefore, we can't make the coordination at the moment.

DESMOND: Basically, I don't believe we will have enough time to finish our project.

PRODUCT

The evening before the final presentation, all the students had been working late and managed to fill the server's hard disk to capacity, leaving insufficient room to transfer files. At the presentation, at which representatives of the monastery had arrived to see the result of the term's work, an attempt was made to clear some disk space to run the program and in the subsequent computer crash more than 50% of the files were lost.

Many files were able to be salvaged as they had been backed up to other machines and to floppy disks, but the task of rescuing the corrupted data was considerable. Six students were employed to work over the Summer vacation to re-draw lost AutoCAD files and complete the project. It is now on display at the Information Centre of the Diamond Hill Buddhist complex.



CURTAIN WALL CONSTRUCTION

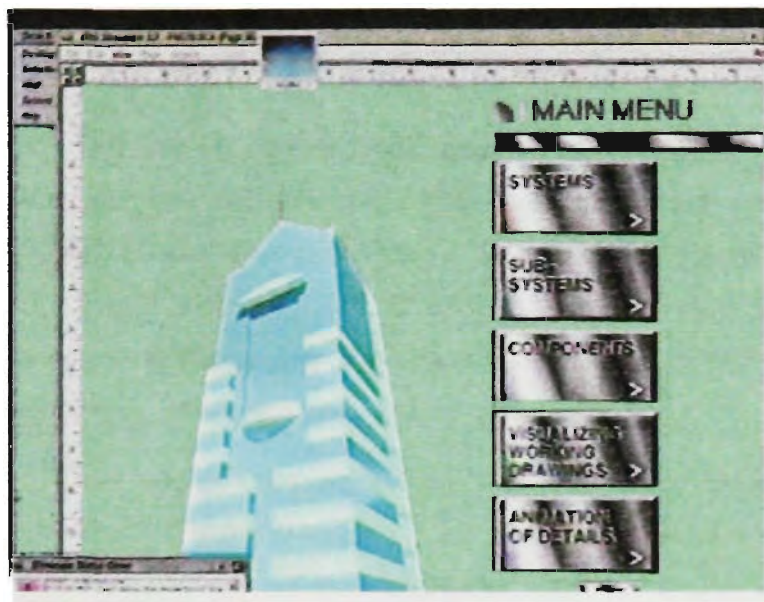


Figure 6-10: Curtain Wall main menu showing the Connaught Rd. Building

AIMS

The aim of the Curtain Wall group was to produce an interactive 3D model of a generic curtain wall building which illustrates:

- (a) The sequence of construction of the building; and
- (b) The standard components of curtain walls.

The proposed audience for the project is future students in architecture, both as teaching material to be used in lectures on construction methods, and as part of the wider “visual dictionary” project. The viewer should be able to assemble and disassemble the building by pointing and clicking in order to see how the components of the curtain wall fit together and understand the interrelationships of these components with one another and with the other elements of the building system such as plumbing, electrical system, fire safety system, etc. It was proposed that this project would be hyper-linked to the

Maintenance group's project, which shares the same model building, as well as to future projects on other aspects of building construction.

From the beginning the members of the group exhibited a high degree of consensus about the aims of the project:

CHRISTINA: At first Barry intended this to be actually shown to the client of the building so they would be able to understand how everything was put together, but I think (our audience is) first or second year Architecture students. They probably won't have too much background in the technical aspects of construction... But really, it's for anybody

FRANKIE: What we are going to do is to create some 3D drawings with interactive functionality so that a layman can have a better understanding of how Curtain Wall systems are constructed and fit together.

WAI: ... We assume that people using the program do not know anything about curtain wall (construction). So, I designed a very realistic image for the building.

FAI: The viewer will be able to select which component they want to look at and investigate it. Then the computer will maximize that specific part and explain it to the user and illustrate its location inside the curtain wall.

GROUP MEMBERS

Christina: her SPQ score shows a combination of high surface strategy and deep motive, which seems to indicate a student with a high level of commitment but uncertainty about what is required of her (her comments about the need to memorize in Hong Kong University courses reinforces this). She was not a strong computer user at the beginning of the term, but progressed markedly under Wai's guidance. Her PFnet demonstrates a very organized and "constructivist" view of the ways in which learning and creativity are related. Christina was the group leader.

Wai: was the top student academically. His SPQ scores are high on deep motive and strategy. A committed and talented student, he won first prize in an international design competition in the course of the year. He began the course with high-level skills in computing, having mastered 3D Studio as well as AutoCAD and his PFnet shows that he has very clearly developed ideas about the relationships between project work, computing and learning. Wai was responsible for most of the conceptual planning of this project and took on the role of “peer teacher” in computing to the other members of his group.

Fai: Also a committed architecture student, though with low SPQ scores on achievement motive and strategy and low skills in computing. Much of Fai’s time was spent assisting Wai in the design of components for the model and he credits Wai with making him computer literate.

Frankie: the SPQ score is average for the class and his computer skills were adequate to the task of designing components in AutoCAD. Frankie was less of a “team player” than the other three, often expressing opinions about the relevance of the project to his own needs. Nevertheless, he made a significant and equal contribution to the design component of the project.

DIVISION OF LABOUR

The four members of the Curtain Wall group worked as a very tight and organized team. They appointed a leader (Christina) who decided that the only fair way of dividing up the jobs to be done was to make sure everybody did exactly the same amount of work. This was not only for reasons of equity but also to ensure that everyone got the maximum profit from the course in terms of domain-specific and computer learning.

CHRISTINA: I am the team leader. My job is to call up all the group members in our group to have meetings ... we actually all contributed equally to what went into the idea of the project.

We made a point to divide the work into four equal parts. It's hard to do that but we tried to do that in the end.

FRANKIE: It is very important that everyone does an equal amount of work so we can all go through the whole process (and all) understand the software and the (building systems) information.

WAI: Up to the current stage, everybody in our team has taken on an equal amount of work ... everyone is assigned to a specific task and then works on it.

FAI: For example, Wai is doing the connections for various parts of the building... Some of us might be slow learners (at computing), so it might take more time for us to finish the work. However, we all have the same workload.

The members of the group worked independently for much of the time, meeting regularly to review progress and to merge work together and in weekly crit sessions to demonstrate to Barry what they had done.

CHRISTINA: ...Each of us did our own work (because) we have our own personal schedules... Sometimes it's a bit hard to get all of them together ... even though it is just only half an hour long (meeting).

The tasks were allocated as fairly as possible:

FRANKIE: We have four members, each one of us is responsible for two detailed parts at this stage... Each of us are responsible for two three-dimensional CAD drawings and then transform it into 3D Studio to do the rendering and animation...

WAI: For example, my task is to create the corner of the building and Fai creates the open window.

In terms of computer skills the group covered the complete range from Fai, who began the term with very little experience to Wai who was probably the most experienced computer user in the class. One of the

objectives the group set themselves from the beginning was to ensure that everyone's skills had a chance to improve through peer teaching.

FAI: Say if one of us didn't know how to do it, we will discuss it together.

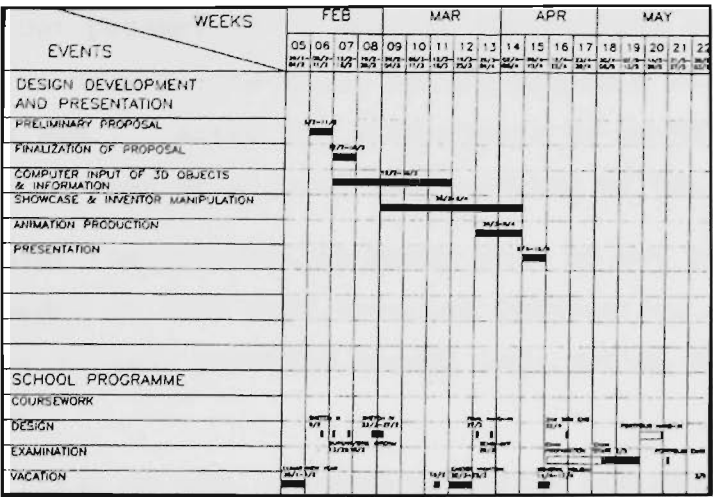


Figure 6-11: Maintenance group’s timetable. They kept to it.

But even with the smoothest organization and the best will, problems of coordination between the members arose – at times one member's work was held up by other students not completing what was expected of them:

FAI: (Demonstrating the project to Wai-ling) This person has done... oops, he hasn't done it yet.

WAI: He is going to do it.

RESEARCH & STORYBOARD

This project is based on a real curtain wall building situated between Central and Sheung Wan, across the road from the Macau Ferry Terminal on Hong Kong Island. The research phase of the project involved visiting the building, making sketches and taking photographs.

The building's working drawings² had been provided to the lecturer in charge (Barry) by the architect and builders. The available material was detailed and comprehensive and the group did not need to search more widely for information.

FRANKIE: Our project is to analyze the curtain wall system. So, at first we have a site visit to the building at Central, close to Sheung Wan.... After the site visit, we produced a set of photographs. Then we started the creation of the storyboard.

WAI: I think the information Barry gave us was quite enough. ... we needed to find some external information about it, however he already provided enough information for us to start the project.

WAI: ... First of all, we need to design the storyboard and then draw out the concept behind by digesting all the information. (In this way) we can then find out which is the best way for us to present the information we have got from the research.

In accordance with the "democratic" style of this group, each member designed a separate storyboard and then the team decided by consensus the most appropriate approach to follow

FRANKIE: Actually, each of us prepared our own storyboard so that we can have the comparison and then get the best combination out of them. Instead of relying on one person to do the storyboard, our group shared the entire work between us... In the meeting, we threw around ideas and had a brain-storming. Then we chose which one is the best way to present it (and the most practical) so that it will match the schedule of our (other class-) work.

² Working drawings are the final, detailed plans for each section of the building provided to the builders by the architect.

The approach was also discussed with the teaching staff before the final storyboard was agreed on

CHRISTINA: He (Barry) didn't really tell us what he requires us to do on this project... he didn't force us one way or the other - we drew up the specifications for it by ourselves.

But the specifications and the storyboard were developed and refined over the course of the project through meetings, viewing one another's progress and weekly crit sessions with the teaching staff. Figure 6-12 is Wai's version of the storyboard, illustrating the construction of a window section.

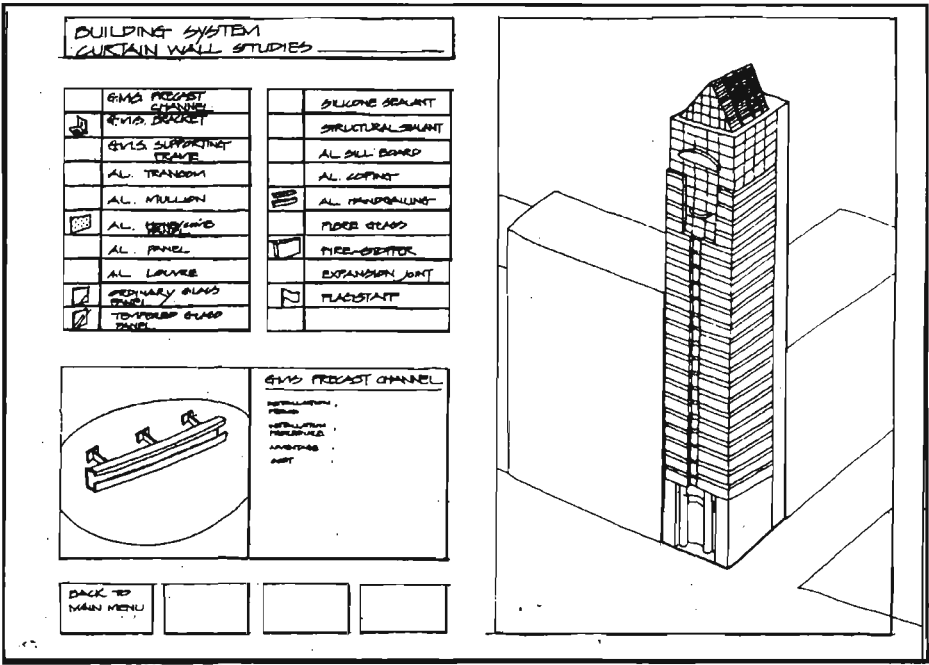


Figure 6-12: Wai's Curtain Wall storyboard

The image represents one Showcase screen, with the curtain wall building in the right hand panel and the components of the window in the upper left. The lower left shows a 3D model of a detail – “GMS precast channel” – which appears when the user activates the hyperlink in the components list above. Four navigation buttons are at the lower left. This storyboard was further refined through discussions with Barry and the

tutors, then developed further into a full colour display, using 3D Studio to produce the images.

FRANKIE: At this stage, each one of us ... will do some rendering and animation in 3D Studio. Then we will start another storyboard which will show the whole view of the skeleton and highlight the elements being constructed.

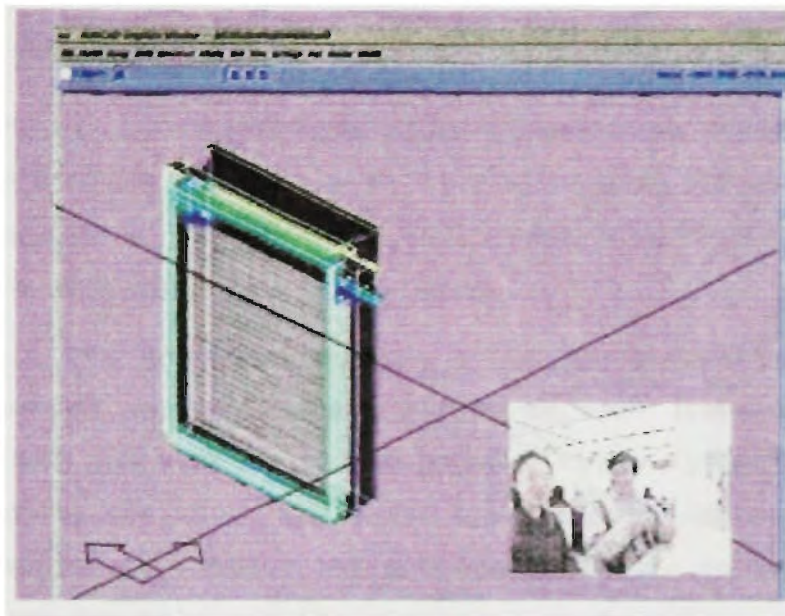


Figure 6-13: Christina and Frankie designing a window detail

COMPUTING

The procedure followed by this project group in terms of their use of computer software was relatively straightforward:

1. Input the data from the working drawings using AutoCAD and create 3D models of each of the components
2. Use FTP to transfer the AutoCAD files to 3D Studio to do the rendering and lighting (See Figure 6-13)
3. Produce animation sequences to illustrate the sequence of construction (see Figure 6-14)

4. Develop a Showcase program as the final presentation in which the images and text files are embedded. (The first screen of the project is illustrated in Figure 6-10)

Unlike the morphing and temple projects, there were few technical problems to be solved and mastering the software seemed to present fewer challenges to the group. On the other hand, they did not find the project particularly stimulating.

CHRISTINA: ... If you have eight elements on which you need to do the details, every one of them has about fifteen components. Eventually, we will need to do it over a hundred times. I think the one who does it will be bored....

WAI: ... The computer can help a lot (by automating) the sequence of actions and the saving of time...the benefits of using the computer is it can provide three dimensions and multimedia for us... the sound and also the organization of information... Without the computer it would be quite boring since we can only see the pictures and diagrams...

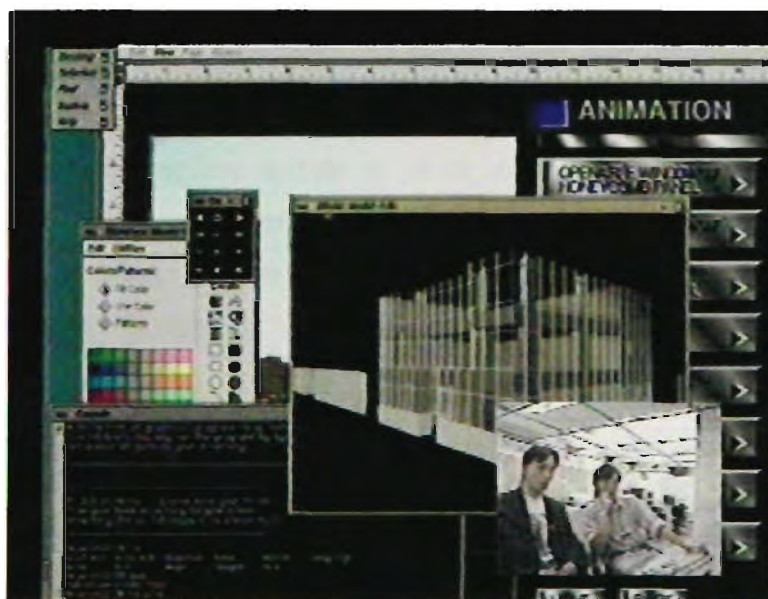


Figure 6-14: Wai and Fai animating the curtain wall model

PROGRESS

Through the regular meetings, the careful planning, the storyboard discussions and the organized system of reporting amongst the group, this team seemed always to be aware of the exact state of progress of the project.

WAI: I think I have about forty percent. We haven't done the main image yet since we left it till the end. We still need to create the sub-system for the building too.

FAI: In my part, I think I have thirty or forty percent left. I am now waiting for the others to merge the system together... I think the rest of the group have only created the 3D model of a specific component... they haven't done the rendering and animation yet... we need to wait for their 3D model and then we can combine all of them together... should be able to produce a completed program and present it to the audience.

The crit sessions, while providing an opportunity for the group to show their work to one another and the rest of the class, also provoked changes in the project. This was often because opportunities arose to develop additional areas or to make additional links. Christina, the project leader, was continually following up her team and reminding them:

CHRISTINA: (Speaking after a crit session - with some irritation?)... we need to change some more features of it... When we had five percent done, we thought we'd linked everything together already. However, the lecturer asked us to link up a bit more...

Christina, more than the others, found the project repetitive and often boring and could not always see the point of producing such time-consuming and detailed work:

CHRISTINA: ... it is very time-consuming to do the details of the components...(and) we still have a lot of rubbish ... a lot of bits and pieces to be done... we still need to combine all our work together. We don't need to create everything again but

we need to make our work consistent together. You see, we have all these different styles for ourselves...

PRODUCT

The group was on schedule and the project was all but complete when the computer crash occurred:

CHRISTINA: We've finished everything within the time for us to present. Unfortunately, we lost them.

Many of the Showcase files were lost in the computer crash, but the major components were backed up and able to be reassembled. The project was taken up by the following year's BSI class and is now nearly complete.

The Showcase presentation enables the viewer to choose a system or sub-system from the menu (skin, window, plumbing, sealant, fire services, etc.) and to examine it in detail. An innovation which this group included was the use of the working drawings as a "visual menu" for hyperlinking to the 3D models. They saw this as an educational device, to assist beginning students to visualize the 3-dimensional structure from the detailed 2-dimensional plans.

FAI: The purpose of including the working drawings is mainly to teach people how to visualize the 3D drawing from a 2D drawing (see Figure 6-15)

WAI: Well, this is the main idea overall: we try to present the way the system is broken down and see the way various parts merge together again from the basic elements to the entire building.

In the following dialogue, Christina demonstrates the Showcase model at the end of the term (after the crash). Although it lacks many components it clearly illustrates what the project will look like when it is completed.

CHRISTINA: We are putting all the information in a Showcase file... You see this is the main menu here. (see Figure 6-10) Well we have four main topics in our system... it shows some

information like the description of the system. Then we can go to another topic which is our sub-system... These drawings are going to be combined with visualized working drawings.

IAN: What's the difference between a System, a Sub-System and a Component?

CHRISTINA: OK a System is the whole curtain wall system including all the components and how everything fits together including the...

IAN: Does it include, say, the plumbing and the fire services?

CHRISTINA: Actually no. Just the skin. A sub-system would be the overall draining system within the whole system and the glazing. (BRINGS UP "COMPONENT" SCREEN) And then this component actually breaks out from the screws to the knobs... and then we go into the... horizontal elements. (CLICKS ON "HORIZONTAL ELEMENTS" BUTTON THEN ON "PRE-CAST U-CHANNEL") Which... I have a picture of it and then, if you want to see an animation of it (BRINGS UP ANIMATION WINDOW TO SHOW COMPONENT ROTATING). (see Figure 6-15)

IAN: This is... what? Part of a window?

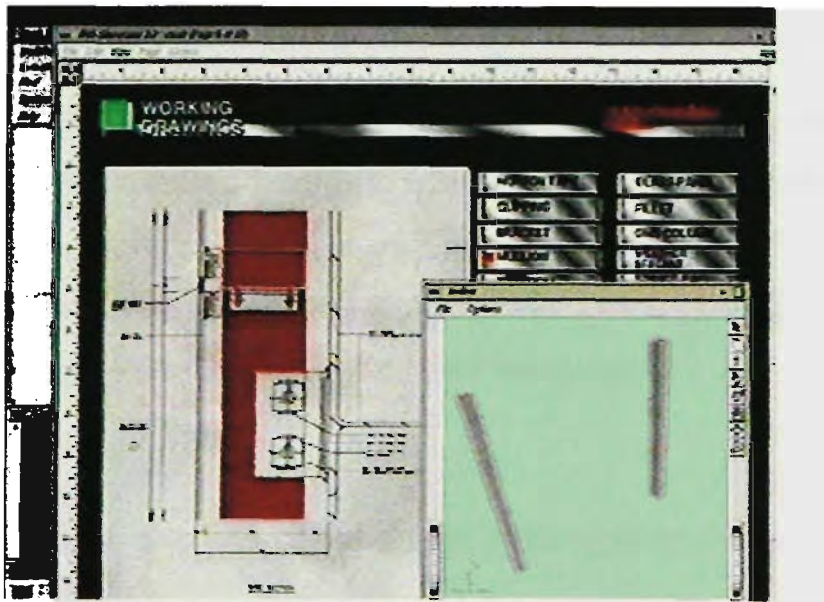


Figure 6-15: Hypertext link from "working drawing" to 3D model

CHRISTINA: This part of... It's one of the horizontal elements. It is the first element that is cast onto a concrete slab and this is where the other elements are added to it. This a U-

Channel... We'll carry onto the next one. This is... (CLICKS ON MULLION) this is one of the vertical elements.

IAN: Are they hyper-text links?

CHRISTINA: Yea. At first I wasn't going to but then I thought I might as well.

IAN: Can you click on one?

CHRISTINA: Yea (CLICKS ON "STRUCTURAL SEALANT". 3D WINDOW APPEARS WITH STRIP OF SEALANT). It just shows that particular component. (see Figure 6-13)

IAN: I see, so it takes us into an animation.

CHRISTINA: And then this one shows you the whole frame if you want to see it (CLICKS ON FRAME AND DISPLAYS WINDOW) Let's look at some of these other ones (CLICKS ON "WEATHER SILICONE" AND WORKING DRAWING APPEARS). At first I couldn't ... I'll show you the animation because it's very hard to show what sealant looks like, because it's not supposed to be stiff, but it's probably the best way I could figure out to get it across. These are hyper-linked too. (INDICATES PINK HIGHLIGHTS ON WORKING DRAWING). (refer to Figure 6-15)

PROBLEMS

During the interviews and demonstrations a wide range of problems was reported. They are classified here into four areas: problems with the computer system, the software, file management, and lack of information. Group coordination and time management were not reported to be problems by this group, which was very well organized.

SYSTEM

Unfamiliarity and uncertainty about the SGI the system consumed a lot of time for Fai and Wai.

WAILING: I see, so you have the full animation for the building as well?

WAI: Yes, perhaps let me show you some of it. Is XANIM here?

FAI: Not sure. You can try IRIS.

WAI: We should have XANIM here, shouldn't we?

WAILING: Where are you?

WAI: This host.

WAILING: Should be...

WAI: You just used it before. This one is a bit slow.

For Christina, the computer systems itself appeared to be a hostile environment which was frustrating to use and wasted a lot of time. She considered it might even be hazardous to health.

CHRISTINA: ... However, I don't like to use the computer tools because it's hard on our eyes and health. By the way, sometimes you will also waste a lot of time on the technical parts.

SOFTWARE

Unfamiliarity with the range of computer software available created problems – the very flexibility of having a range of programs to use could appear to be counterproductive.

FRANKIE: Sometimes we found that there are some commands which seem quite confusing, (often) we can use different commands to perform the same action. At other times there are some commands which used to work but all of a sudden they didn't seem to work anymore. It's very frustrating.

FILE MANAGEMENT

Just as the project appeared to be 90% complete, files were lost in a computer crash.

WAI: According to the content of the work, it's about sixty or seventy percent (lost). About the data, we have actually lost the Showcase files. These are the jobs which take time. The other jobs like the animation, the computer does the job. But we had a lot of input in the Showcase

CHRISTINA: Actually, we lost most of the Showcase file... I think at least seventy percent was lost. I think the Showcase

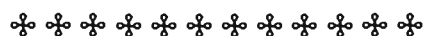
were a lot, but the images are mainly the animation.

(Fortunately) We have all made backups of some of the files.

LACK OF INFORMATION

Unlike the Maintenance group, which had difficulty finding information about the subject, the Curtain Wall group's main complaint concerned lack of information about the seemingly open-ended nature of the requirements of the project.

FAI: Communication is really a big problem. Sometimes we need to present it to the lecturer. However, before the presentation...., he (the lecturer) didn't tell us about the requirement. Every time after we've shown it to him, he will ask us to add a bit of this and a bit of that. You see, it takes a long time for us to finish a part of it. Especially the animation consumes a lot of time for us to render. Therefore, sometimes it seems like the project will never end.



BUILDING MAINTENANCE

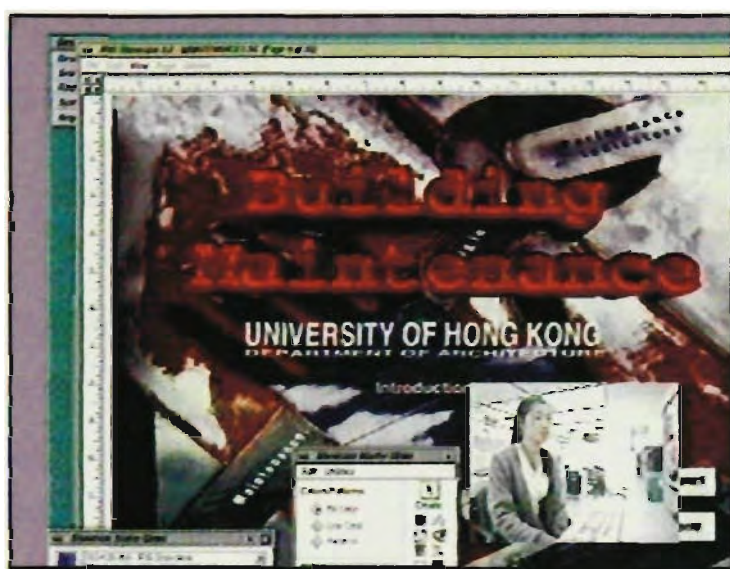


Figure 6-16: Introductory screen of the Maintenance project

AIMS

This project was conceived to be complementary to the Curtain Wall project. They would use the same building as the model and while the other group would construct the components of the model, this group would develop a maintenance “matrix” for these components. At the beginning of the term, the group appeared to be somewhat unwilling conscripts. They had had no choice in the topic and found it difficult and uninspiring with little, if any, design work. Additionally, none of the group appeared to be clear about what maintenance involved. They spent a long time trying to decide what strategy to follow.

MAN: The worse part is we didn't expect anything at the beginning. We didn't know what things we can do for the title of maintenance. Barry suggested us to have this project title.

SHIRLEY: We are trying to see what sort of maintenance will be needed when we build a (curtain wall) building. The aim of our project is to find out the most important (aspects of)

maintenance, so that we will know what kind of maintenance is needed for other buildings as well.

MO: Maintenance is a pretty large area. Lots of things like air-conditioning, the problems of wind, fire, water and electricity are also taken into account for the building services. However, you should bear in mind that building services is only part of the maintenance.

The fact that the Maintenance and Curtain Wall group were "sharing" the same building, required some coordination between the two groups, particularly in basic matters like the availability of working drawings and CAD models. Towards the end they would need to create links between the two projects.

MO: ... our group and the Curtain Wall group are using the same building as the case study... So, in the early stage, our ... will be quite similar. However, at the later stage, we will develop our ideas and content (in different directions).

Joan saw the situation in more concrete terms:

JOAN: In fact, Curtain Wall is part of our system.

GROUP MEMBERS

Mo: a highly skilled computer user familiar with both AutoCAD and 3D studio. Mo did all of the animation in this project. For much of the time he did not appear to be happy with the open-ended nature of the course, which is possibly explained by his very low SPQ scores in deep approach – he would have liked more direction from the teachers. His PFnet is a "star", totally computer-centered. The group elected him leader.

Joan: a graduate of the University of Sydney. She began the term as a weak computer user, but showed obvious progress by the end of the course.

Joan's SPQ score is extremely high on deep approach and extremely low on surface – her approach is deep to a fault, as she explains:

JOAN:...for me it is difficult to put things in a very organized way, cause I am always jumping from one area to another.

This is well illustrated by her "cat's cradle" PFnet. Yet Joan was normally the person who presented the group's work-in-progress at the weekly classes and became the *de facto* leader of the group.

Yat-man: (a.k.a. Man) His SPQ score is extremely low on surface and achieving and below average on deep motivation, which indicates that he was having difficulty relating to learning at this level. His computer skills were adequate, and he did much of the Showcase work in the project.

Shirley: had come to HKU the previous year from the University of Melbourne. She was a 5th year student and consequently had less time to spare for the project than the rest of the group. Her SPQ score shows extremely high strategy scores in all areas – both surface and deep – which possibly indicates that she is prepared to take whatever approach gets the best result. She had learned AutoCAD in her undergraduate course so had basic computer skills

DIVISION OF LABOUR

The group found it difficult to develop an ethos. There were no pre-existing friendships and there seems to have been little in common. Shirley was 5th year student, a year ahead of the other three. She and Joan had both done first degrees in Australia. Although Mo had been elected leader, he showed little inclination to organize the group's work.

MAN: We haven't got a team leader...

SHIRLEY: Each one of us has different tasks. We will work on the area which is most familiar to us.

Of the four members of the group, only Mo was a keen and experienced computer user. Joan and Shirley had done some computer-aided design in Australia but were unfamiliar with the SGI system. Yat-

man had not used AutoCAD since second year. They realized that they would need to develop a strategy to acquire sufficient computer skills to cope with the requirements of the project.

MAN: We have four persons in our group. One of us is very keen on computing. We will ask him to learn the technical skills first, then we can ask him to teach us when we need to do the applications. This is for the technical part. About the contents (of the project) we will have meetings and then discuss together. Say, we will go out and collect the information together.

At the early stage of the project, research was the first priority, then the organization of that research into a form which could be put into Showcase (presentation software). Joan and Shirley, who had the least interest in computing, worked together on the research, but it was not until the mid-point of the project that they had all found a comfortable role..

JOAN: (My role is) Research and part of computer data input.

SHIRLEY: I have the same role as Joan because we did it together. We collected the research information and then divided it into different sub-topics ... I think I will create the image in a later stage of the project. I will try to use Showcase or Inventor.

YAT-MAN: I collected their information and also I found some pictures or images that matched the content and then input into the Showcase of the SGI system... So, my role mainly is to edit the information and (put it) into Showcase.

MO: Me? I contribute to the computing area mainly. You see, most of our team members are not familiar with the computer. This project, however, requires lots of computing techniques to do the presentation...(My role is) more technical because I think I am the one in this group is more familiar with computers (and software) such as 3D Studio. My role is to ask

them what do they want to show and I try to make the object to be visualized. Say, to change the image (indicates image in the margin) to a real animation and how to develop the idea.

STORYBOARD

The first stage of the project involved creating a storyboard, using pencil and paper. This needed to be discussed in class and approved before they could proceed further. Maintenance, being a more abstract concept than either Curtain Wall or Temple, took some time to conceptualize:

MO: The storyboard describes what sort of components are involved in the entire building. So that people would be clear about the structure and skeleton of it. Once we have the structure of the building, we can then start to analyze the building system, building surface and structure of it.

The proposed audience was the same as the Curtain Wall: undergraduate architecture students. Their first ideas were quite ambitious: to create an exploratory environment offering the viewer a great deal of choice. Somebody had recently brought in a copy of the simulation game "Sim Tower" (an offshoot of "Sim City") in which the player races against the clock to build an office tower and then has to manage it within financial parameters in the face of a sequence of natural and man-made disasters. However they soon realized that this approach was well beyond their computing abilities and would have been unrealistic in the available time. Finally, they settle upon a much simpler plan employing the metaphor of a lift within the curtain wall building: press the lift button to go to the appropriate floor/topic.

JOAN: At first, we tried to use the model of "Sim City". However, it was too complicated for us to do it. So, we changed it into this version.

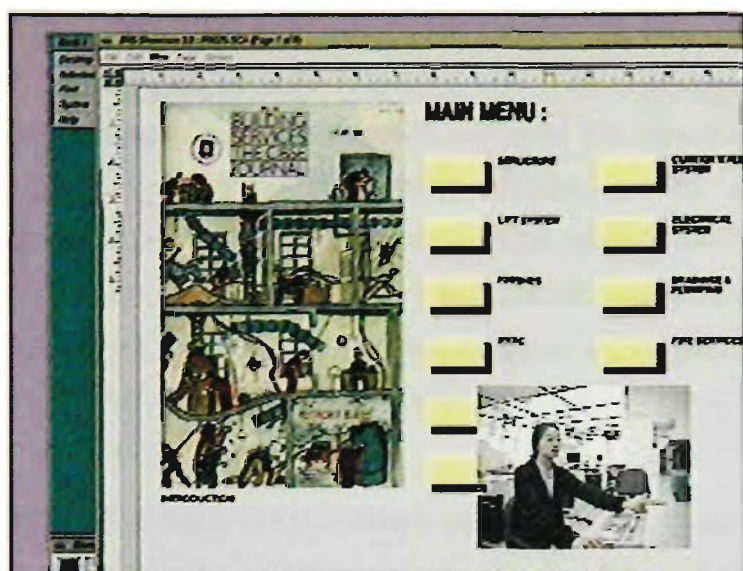


Figure 6-18: The "lift" menu

SHIRLEY: ... If we still have time, we will do the air-conditioning too. However, it all depends on our progress. And we will add one service every time. For example in the lift service, we need to have a lift shaft. Then we can think about what sort of maintenance is required – say what ... elements and components need to be maintained within five years. The choice of the materials might also affect the time interval for us to maintain the building. We will list all this information out and then produce a standard format for it. Maybe we can draw some conclusions about the life cycle of the lifts in the building.

RESEARCH & ANALYSIS

Research and analysis took a great deal of time for a number of reasons: to begin with, the team could not agree on which aspects of maintenance should be included; additionally, there are few texts on maintenance and they had to hunt down manuals and technical journals and to approach maintenance contractors, who were not very forthcoming.

JOAN: At the beginning we have no idea about how to do this project, then we've got to search all the information from the books and materials.

WAILING: So, how did you overcome the problem?

JOAN: We kept reading and finding out information from books and people. There are different aspects of maintenance - like the air conditioning and the lift system... the structure. We are doing it like a book. There is one aspect of maintenance, known as "corrective" and after all this research, we still don't know what it is... (At the beginning we were) not really sure what maintenance is. At least research work has given us a deeper insight in this topic.

The project fell a long way behind schedule and even two weeks from hand-in time they were still attempting to find more information:

MAN: I think we are still in the intermediate stage We are still collecting the information at the moment.

The final form of the project included only four aspects of maintenance, although there was now a structure which could accommodate more in the future.

IAN: How many sub-topics do you have then? Lift system,

SHIRLEY: ... Curtain wall, air conditioning, lighting.

COMPUTING

The second stage of the project involved fashioning the research material into a hyper linked presentation in Showcase, which included text, graphics, audio and animation. This required knowledge of a variety of computer software as well as mastery of the multimedia lab and SGI environment, which most of the group lacked.

MAN: At the beginning, we don't know what can we do in SGI, so we need to see what sort of software are available. Then we need to decide which software is more suitable for our presentation. After that, we can finalize the storyboard and start to work on it. Basically, we (first) need to find out what sort of software are available for us to use.

MO: You can say (the thing missing for our group) it's software knowledge. I think we should know the basic software as 3D Studio which performs the animation for you, AutoCAD for the geometry and some production tools such as Animator Pro too. Besides, we also need to know other morphing programs as well.

MAN: Well, I think we need to do the animation and the presentation. At the end, we will put everything into Showcase and then link up everything together and present it there. What I am doing at the moment is trying to put the information into the Showcase software. (This involves) mainly graphic design, something like page layout design.

Three dimensional imaging was to be a central component of the presentation and the lack of experience in the group was proving to be a handicap. The only member of the group capable of handling this software was Mo, but unlike Wai in the Curtain Wall group, he was not able (or willing) to become the "peer tutor" and preferred to work alone. This meant that the weaker members of the group were restricted to working in Showcase.

MAN: So far, we can do two dimensional image in Showcase. What we are working on at the moment is how to create a three dimensional interactive image in the layout of Showcase. So that the user can read the information and also play around with the model as well. We are learning how to do it now.

PROGRESS

There were two main problems which dogged the group: the difficulty of finding adequate information on maintenance and their lack of computing skills. The only easily obtainable information was on lift systems so this became the starting point:

MO: Basically, we will create the lift system first. Once we have enough time and information, we will then create different kinds of building systems. I am sure we won't be able to finish all of them anyway.

The lack of computing knowledge was handled by requiring Mo to undertake most of the complex work. There was, however, a fair amount of experimenting and prototyping to be done before the form of the project could be finalized:

MO: (Explaining that they are still in the prototype stage).
This one (showing screen image) doesn't match with our storyboard ... it is mainly for us to test the animation effects and techniques. There is not much relationship between the storyboard and it.

But, once the "Lift" metaphor had been decided, the group was able to concentrate on the look and feel of the project:

JOAN: We found (this image of the building) from a magazine. (see left of Figure 6-18) We can create a linkage which will bring us back to the previous page. There is another link in the Showcase which will go to the Curtain wall system.

Joan demonstrates how a button in the Maintenance interface is designed to take you into the Curtain Wall project. At this stage the Curtain Wall group has not provided a button to get back. In a weekly crit session, Barry pointed out the importance of coordination between the groups and the need for uniformity of screen design elements – particularly button design.

JOAN: ... OK, let me go back to our Showcase. So, we came back from the Curtain wall Showcase to Maintenance Showcase. Another thing we (plan to) do is to create a section which will present (audio information). This one allows us to record some voice into the sound track. For example, we will store some dialogue for the introduction.

Another problem which concerned the group was what they saw as the lack of creative possibilities in the topic. After rejecting the Sim City model as impractical given the time and skills available, they spent a great

deal of time discussing and trying out ways to improve the appeal of the interface and make the topic more appealing to their proposed audience.

JOAN: Em, what else should I show you? OK, when we come back to the main menu, you can see there are some icons like the lighting and fire services. We are going to add some information to them. We have changed quite a lot in our new version. The current system is rather dull now, but we will try to make it become more user-friendly.

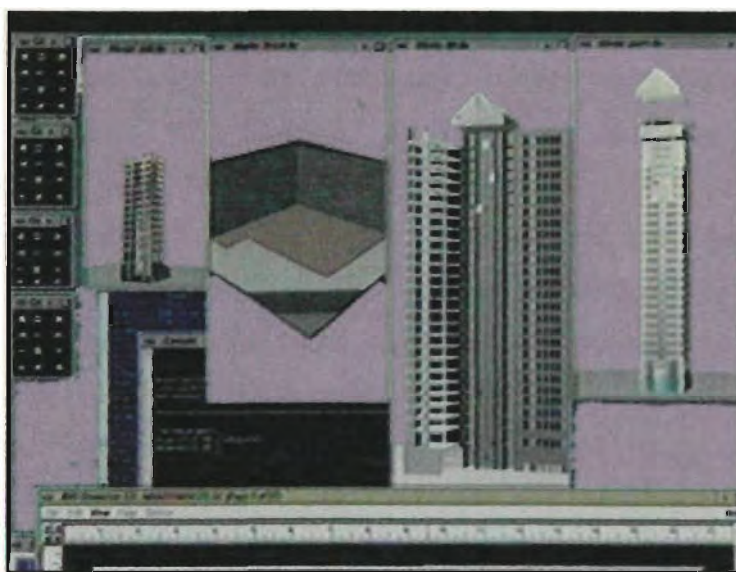


Figure 6-19: Three animation sequences from the Maintenance project

By the end of term, the structure of the project had been fixed and much of the textual information for the four Showcase pages had been written. Mo had completed three animations (Figure 6-19 - left to right):

1. Construction components of a concrete and tile floor section;
2. Lift system, in which the front of the building opens out to reveal the lift shaft with animated lifts and counterweights;
3. Construction system loop showing the sequence of construction of a curtain wall building.

Mo demonstrates them to Ian and Wailing:

MO: ...For example we try to show how the components of (the finished) system work... (DEMONSTRATES CONCRETE FLOOR SECTION) for example we have some screeding and some cement binding and the tile is put on. In the program we will propose what kind of defect will appear in this part. And about the Lift System (INDICATES MIDDLE SECTION) which will demonstrate how the lift and the machinery works, but maybe the animation is not so detailed. It will show the repairs. And this one... (INDICATES THIRD ANIMATION - RIGHT) tries to show how the building components are sandwiched together in the curtain wall part. There are some technical problems. (SOME COMPONENTS ARE OUT OF SYNCHRONIZATION) The effect is quite interesting but not so informative.

IAN: This is meant to show the sequence of construction?

MO: Yes. But if we follow the actual procedure it will take a very long time and the file will be too large. So I squeezed the time so everything happens at the same time. The structure should be complete at this half of the building and then the curtain wall should be mounted on the superstructure. But not in this case, it seems the curtain wall and the structure (are both) completed at the same time. There should be a time lag.

Mo had produced the animations, working independently of the others. The question now arose as to how they would be linked into the Showcase presentation.

MAN: The main framework of the content is already done. The only thing left is the images (to go with the text pages). We are going to scan the images later. Then we will insert the photographs and also the animation. Finally, we can create some linkages.

Although the project was still only 75% complete at hand-in, due for the most part to lack of coordination, the group was very happy with what they had achieved. They felt that they had learned a great deal about the subject – realized how much they still had to learn, both about maintenance and about computer design and presentation.

MAN: There are a lot of things we still need to learn. We know very little at the moment. The skill we have is kind of surface skill, not too much details at all.

PROBLEMS

The Maintenance reported the greatest number of problems of all the groups: in particular, the relatively low level of computing skills of three out of four members and the difficulty in finding source material on maintenance.

INEXPERIENCE WITH COMPUTING

Yat-man in particular, was frustrated by his inability to operate the SGI system and complained on several occasions that this was an unreasonable demand:

MAN: The hardest part is to learn the SGI system ... The most important part is how to manipulate this machine ... the way how to merge everything together It would be better if they can teach us the basic skills of the system, then we would be able to cope with the new system.

IAN: Nobody taught you?

MAN: they didn't teach us anything, when we start the course, they required us to create the application immediately. It becomes more difficult for us. You see, we need to learn a brand new system in this year. If you haven't got enough time, then you can't be able to learn the fluent skills for it at all they assume that we will learn the system by ourselves ...

IAN: How did this affect your project?

MAN: I think the system is new to us and we don't know how to use it at the very beginning so we really need to spend a lot of time to get used to it. So it actually wasted a lot of time. I think if the department can teach us then we can concentrate more on the content.

INEXPERIENCE WITH SOFTWARE

Lack of familiarity with the software lead to difficulties with translating concepts into practice. Animation, in particular, presented difficulties:

MO: I think it is the problem of the software, therefore, the animation is not very smooth though. Since the information is pulled out from the hard disk directly, perhaps the access time of the machine cannot provide the speed of the frame movement. Therefore, there are some missing frames as you can see.

IAN: Do you know how to make it look better?

MO:

No, I don't know. I really don't know what to do. We can't really ask people all the time. There are so many problems. This kind of system and software is really big. All sorts of problems will occur at any time. It's not enough to know one or two things only. For example when I created this animation, I needed to know how to create the image. Then, I needed to know how to convert the image from PC to SGI. After that, I needed to change its format from SGI, so all the images could be linked up and produce the movie. I think I am more lucky because I heard people talking about it before, so I know it can be done in this way; otherwise, I wouldn't know how to start. I wouldn't even know it could be done at all! The main thing is I don't know what kind of questions I need to ask. And even though you ask them (the tutors), they wouldn't know what you want to do. Or perhaps it is so complicated that they would not like to tell you at all!

INEXPERIENCE WITH FILE MANAGEMENT

The group had many bad experiences with losing files. In most cases this was due to poor file management – lack of experience again – but it was also a consequence of a great many students using the system in an undisciplined manner. Joan and Mo both reported a frustrating evening spent by Yat-man:

JOAN: We were working on the latest version yesterday, unfortunately we lost it. Yat-man was doing it till twelve o'clock at night, but he lost it all due to "Fatal Error".

MO: I have a classmate who created a lot of linkages yesterday, unfortunately, he had a "Fatal Error" at the end. It might be due to the hard disk filling up or something else. Eventually, he lost everything he did At the end, he left the lab in total frustration In fact, there are a lot of problems when we are doing this project.

INADEQUACIES OF THE SYSTEM

Mo, the most experienced computer user, was also concerned with the lack of training in software and found working in the laboratory to be a frustrating experience. The system was often slow and access to machines was restricted.

MO: If they insist that the project has to be done by SGI system, then it would be nice to have some sort of training for us Another problem is the machines are really slow. I don't know the reason because they are suppose to be very fast Now I found that they (PC and SGI) are quite similar in terms of speed. I really don't understand it. One more problem is we have not enough machine here. Those machines - the faster and more powerful ones - we have only five or six of them

LACK OF INFORMATION

This was a topic where the normal research resources of text books and references were of little use. The only books they could find in the university library were out of date. In order to find up-to-date information the students needed to approach construction companies and to find trade catalogues.

MAN: We are trying to look for this information but it is quite difficult to find.... No, there are no references at all. The books are not that up-to-date neither. The buildings that

the books mention are the old English style models just two floors high.

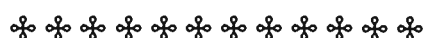
SHIRLEY: When we interviewed people in the maintenance area, they wouldn't really go into detail with us. They would ... tell us the cost of a system with different speeds... When we asked them for information about the system, they just gave us brochures about their companies and systems, they didn't give us any detailed structure information. Now we are trying to ask the lecturers to see whether they can suggest some other sources to us.

MAN: No, we haven't (got any external advisor to give us the information). We base on the existing commercial building to be the background of our project. Then we will apply the maintenance issues on top of it we don't know what we were doing at the beginning of our project.

TIME MANAGEMENT

The group ran out of time and did not finish the project.

MO: As I told you before, maintenance is a very wide area. There are a lot of elements involved in this term. We might focus on a few areas like structure, lift and see how it goes. There are some more modules in the main menu which we haven't got enough time to finish (so we will) will pass it on to the students in next year (1995-96). Perhaps they can finish it for us.



MORPHING STRUCTURES



Figure 6-20: Waiman designing the opening screen

AIMS

The primary aim of this project is to illustrate the development of roof styles over time, from a flat roof on four pillars, through various types of arches and vaults to domes. Morphing can make any shape transform into any other shape, so secondary aim was to show which types of transformations are valid and which intermediate shapes were needed in order for buildings to progress from one historical style to another.

Like Curtain Wall and Maintenance, it is primarily an educational project, aimed at an undergraduate architecture audience.

The Morphing project had two objectives:

- (a) To illustrate the way in which one roof shape can evolve into another;
- (b) To provide an accurate historical picture of the way roof shapes evolved over time.

WAIMAN: We are trying to see how (a roof style) can change from one structure to another for example, we want to see how

it can change from a flat plane to an arch and then from an arch to a dome. We also need to reflect the historical development...

DEFINITION

Morphing is a visual effect in which one object is dynamically transformed into another. Unlike the film/video "dissolve" effect, which overlaps a "fade out" of scene A with a "fade in" of scene B, morphing is an animation technique performed by the computer in which the impression is created that object A appears to "grow" into object B. The animator can control the morph by defining the way in which each point in image A transmogrifies into the equivalent point in image B..

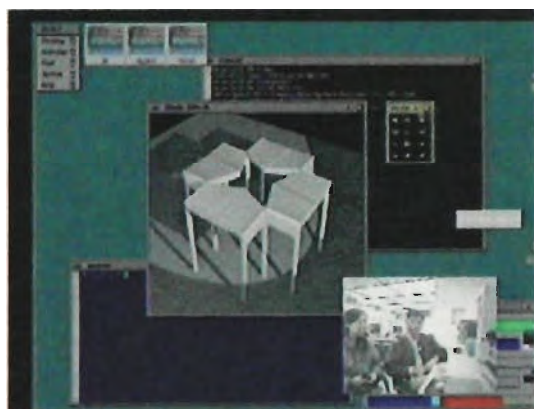


Figure 6-21: From flat roof to...



Figure 6-22: ... groin arches

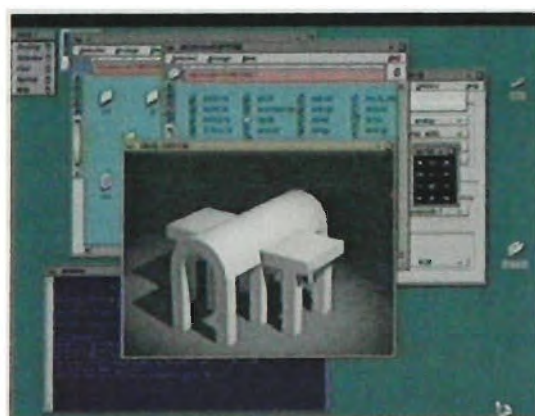


Figure 6-23: From barrel vault to...



Figure 6-24: ... dome.

Morphing software is now commonly employed in the feature film industry and in TV commercials to create digital special effects. Morphing effects can be produced by 3D Studio as well as several other software programs in the multimedia lab. Figure 6-21 to Figure 6-24 provide illustrations of the process

GROUP MEMBERS

Han: was the group leader. She is well organized and self-disciplined and used these skills to keep the project on track. Han's SPQ scores are high on all scales, but above average on deep motive and achieving strategy. Although her computing skills were only average, she displayed a high level of contextual knowledge. The PFnet also illustrates her clarity of thought.

Howard: His SPQ exhibits the *high deep strategy – low achieving strategy* common to other dedicated computer users and his PFnet is a Web pattern with the focus on computing. Howard was almost solely responsible for the animations in this project.

Waiman: was a competent computer user, but her SPQ and PFnets show her to be a student without a great deal of self-confidence. She was a quiet and conscientious worker, always in the background, hardly ever appearing at the class presentations.

Lun: was not present at the beginning of the term, so no SPQ score was obtained. He contributed to several of the group discussions, but was otherwise not part of the study.

DIVISION OF LABOUR

HOWARD: We have divided into two groups. The first group is concerned with the story of the project – how the structure is morphed and the names of the structures (roof shapes) because

we want to draw historical references for the structures. The other group is responsible for the technology, they are researching the way to handle the software to achieve the morphing (effects) of the structure.

Howard, a skilled AutoCAD designer, took responsibility for researching and learning the computer techniques. He enjoyed the challenge but was sceptical about the original brief (to produce an interactive morphing project where anything could morph into anything else). He was concerned that they might get too ambitious and try to do things which were beyond their computing skills or technical capacity.

HOWARD: My role is mainly to produce the morphing animation and I need to research the methods to produce the effect I also need to revise our overall proposal (in the light of) the technology and the skills we have between us. If there is something we can't do we have to cut it out (of the storyboard).

Han and Waiman developed the storyboard and looked after the historical research, although Waiman states that there was no leader she means it in the sense of a rolling creative vision. Han organized the group and ensured that the schedule was kept .

WAIMAN: We haven't got a leader at all.... I think we will divide the work into a few parts and then each one of us will share the same amount of work..... Occasionally, we may have somebody who is very keen on a particular part. However, nobody is responsible for working on the same area all the time. We don't work in that way.

But they did work in this way. In the end it was Howard, assisted by Lun, who produced all the morphing animations.

HAN:... Waiman and I are doing the Showcase We also coordinate (the work of) the other two.

Apart from the pragmatic justification that the detailed modelling work required high-level computer skills, the group also had an aesthetic justification for dividing the work in this way:

HOWARD: We might actually obtain a more consistent style between the objects we created if we divided the group according to the nature of the task. Say, if all of us were doing the animation of the modeling, the image might turn out to have different styles...

HAN: If there are too many people (doing the same job), we might have different opinions. This is the reason we are working in teams of two persons.

RESEARCH AND STORYBOARD

Morphing effects cannot be displayed and manipulated in "real time" like a 3D model. The sequence of the morph must be designed, then the computer produces a series of still images which are combined into an animated sequence. The operator has a great deal of control over the sequencing and timing of the morph and is able to choose the significant vertices in the two images which will "grow" into one another.

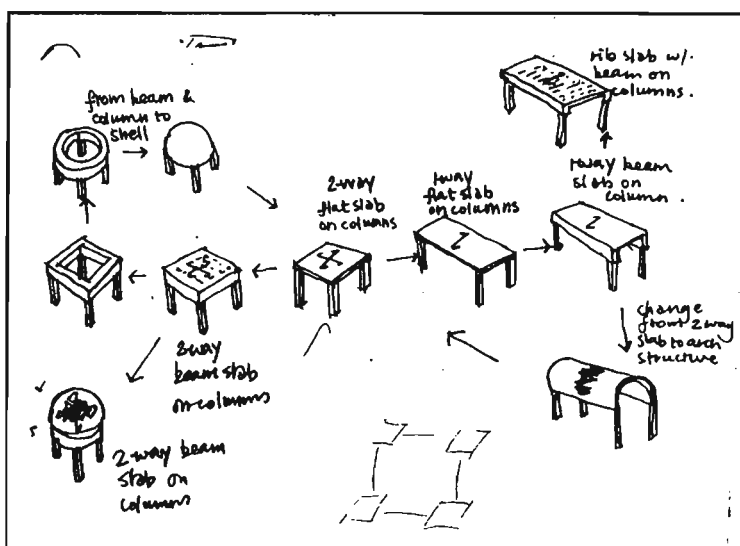


Figure 6-25: Preliminary plans for possible morphs

In theory, morphing can produce a transformation from any object to any other and in television commercials and music videos the technique is primarily used to produce startling effects. It might be possible to show how a Chinese temple could be transformed into a Gothic cathedral, but such a development has neither structural nor historical validity. In this project it was important that only *possible* and *historically correct* transformations would be allowed.

HOWARD: The other important problem in the storyboard of the morphing process is.... it might not be the case that all kinds of structures can be morphed we might want to morph one object to another (which are) different structures ... we need to do some research to see whether that particular shape could be morphed or not. It becomes the problem for both sides... It might occur to us that there is not any intermediate shape which can be created for these objects. Therefore, we need to do some research to see whether that particular shape could be morphed or not. It becomes the problem for both teams....We will try it out step by step. Well, if we still get stuck at the end, we will find out some information from books. However, even after you read the book (and find the shape), you still need to try it out again to see how it works.

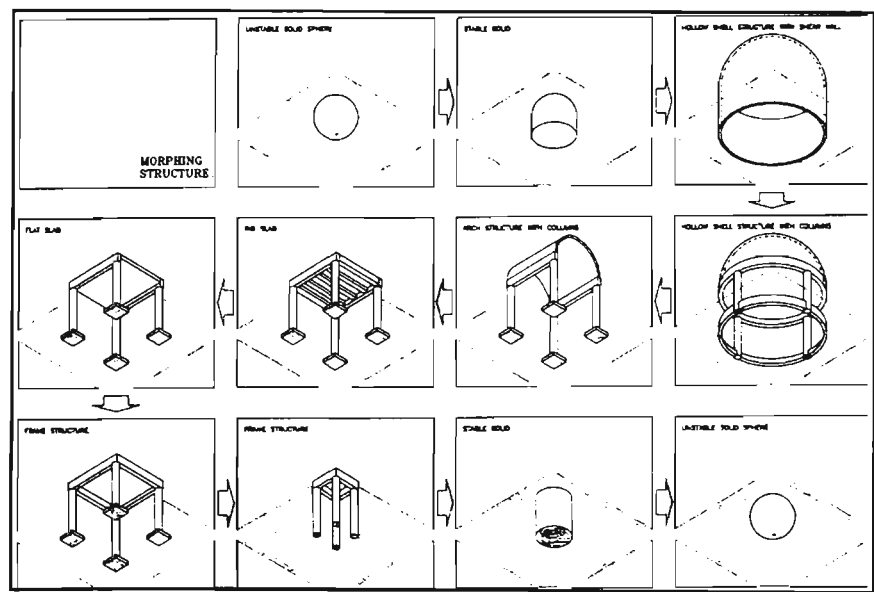


Figure 6-26:Storyboard showing possible morphs

The first storyboard idea was a straightforward historical approach, illustrating the development of European or Islamic roof styles from flat slab through the keystone arch to the Gothic vaulted arch and into the Islamic mosque and Russian onion domes.

HAN: I am designing the storyboard and we also have the idea. We know the way to draw different parts of the storyboard and the idea is enough for us to create the Showcase.

WAIMAN: Basically, we have nine sections (basic shapes) in our project we need to design the sequence of the steps for the final sections..... we want to embed some background meaning behind it we need to find out a way which is more suitable for the morphing of the structure.

The research team set out to find examples of each style of roof which could be used in the Showcase presentation to illustrate the morphed shape. However, the sequence proved to be difficult to illustrate, and there was a particular problem in finding examples of intermediate shapes. They then changed the approach and decided to make it a game in which the the user had to guess which shapes were transformable:

HAN: We are going to present the picture in black and white. We will then merge the ... animation modules onto each one. Another thing is we might put a photograph of the building as the background so that the user could more easily imagine what the process of the building looked like. (See Figure 6-28) Perhaps it would be more easier for them to understand the structure of the building if we do it in that way.... we can apply the linear approach on to this game, then we will have a stronger (linkage) relationship between the pictures.

WAIMAN: The way how to link up all these together is the most difficult part ... So, we need to arrange them in a suitable path we arrange it in a form like a game We are worrying that the user wouldn't know how to play this game. However, we don't want to present too much text to the user because it would become a bit boring.

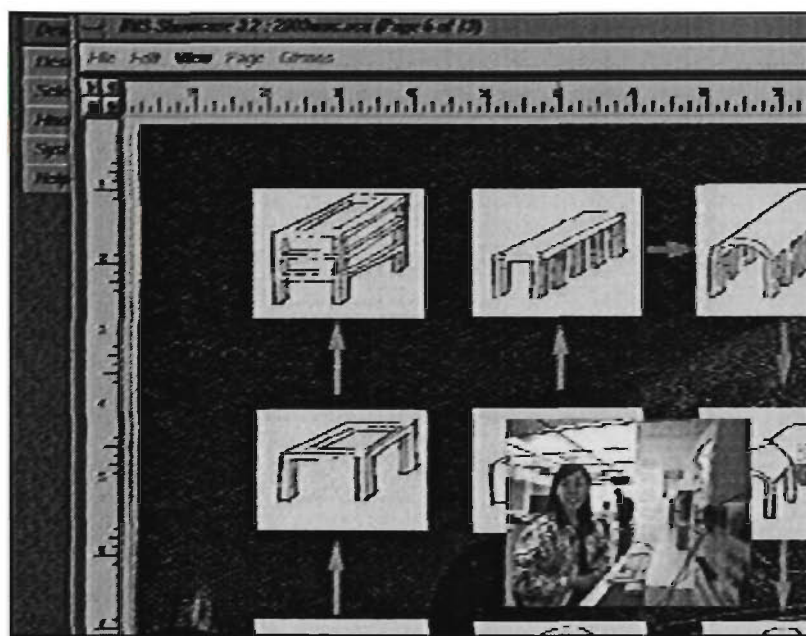


Figure 6-27: Han designing the "game" storyboard

The game icon with nine shapes became the project storyboard. (Figure 6-27) The user would be invited to guess which shapes could be morphed and which were impossible. This non-linear approach required a great deal more programming, modelling and testing than they had originally planned for

WAIMAN: After we've done all the testing, we can then do the development by ourselves individually. Actually, it is not difficult to produce this kind of image, but the way for us to test it out is the most difficult part. I will (test the game by) pretending I am the user who is playing the game.

This was a difficult conceptual problem, which proved to be a difficult concept to "sell" to the class during the crit sessions as they found it difficult to visualize the way the "game" worked and how the animated sequences would be displayed.

WAIMAN: we will show it to others to see whether they understand it or not Barry said he does not quite understand it, we need to do something about it. We didn't ask anybody to test the system but tried it out by ourselves

COMPUTING

The Morphing group followed three steps to produce their project.

1. The basic 3D building shapes were produced as AutoCAD models
2. The 3D images were moved into 3D Studio for rendering and for producing the morphing effects. These frames were sequenced and timed and programmed into an animation.
3. The game lay-out, the photographic backgrounds and the animated morphing sequences were included as components of a Showcase presentation with hyper-links.

HOWARD: We've never used this kind of morphing technique before. It's a bit new for us so we need to keep trying out to see how it works. It is the problem of developing new skills.

Howard needed to develop a means of establishing whether a transformation was possible. He could only do this by examining each frame within the animation sequence.

HOWARD: Our (objective) is to morph the object from structure A to structure B. Using the frames of animation we can examine the intermediate images or structures to see whether it works or not. Although structure A and structure B might work fine, the most important thing is we have to make sure the intermediate structure works fine as well.

... To handle the morphing by the computer is not very easy..... We need to work very slowly... to do them a little bit by a little bit. It is a bit of a waste time

The level of computing skill required to do this work was quite demanding. Howard found the process difficult; Han and Waiman found themselves struggling to use the software and understand the process.

HAN: Animation, and the morphing parts should be the most difficult ones (and) the investigation of the morphing techniques is the hardest part of all.... (But) how to operate

the Showcase system is even more difficult I think the difficult part for Waiman and me is to understand the concept of Showcase.

PROGRESS

The group took a long time to establish the direction of the project as the first few weeks were spent coming to grips with the complexity of the computing process. Howard began producing the shapes and morph transformations, but for some time it seemed that this was the only part of the process which was happening. The "learning curve" was very steep.

HOWARD:.... we finished about fifty percent of the whole project if we consider the technical issues together. (Now that) we have obtained the skills already it will be faster for us to create the rest of the model.

The weekly demonstration sessions were difficult for the group as they were trying to present an idea which was conceptually very difficult. They were frustrated by the feeling that the teachers and classmates could not understand what they were doing so tended to criticize details of their work.

WAIMAN: (Demonstrating a transformation) We've finished this part already. However, Barry said that there are too many lines on top of the roof, and we are trying to remove these lines at the moment to find out a way to do it We are still thinking about the way how they change, so you are not supposed to see this object at the end of our project.

It was the decision to develop it as a game which eventually kick-started the group and set the framework for the project. This did not necessarily speed up the process but it gave direction to Han and Waiman in particular so that by the end of term the group was working at a creatively high level.

WAIMAN: We need to learn how to do the morphing effects here ... we also need to learn the technical issues as well

.... On the other hand, we need to find out the historical background of the building I think our project requires a lot of imagination and creativity from us.

HAN: Actually, we still have a lot to do. You see, even though we have the back-tracking functionality, we also need to design it in such a way that the user would know how to play the game once they got into the system.

PRODUCT

At the end of the term the project was not finished. It suffered from the system crash along with all the other projects, but Howard had backed up all of the shapes and transformations so only the shell, which had been developed in Showcase, was lost. The project was brought back to its pre-crash form over the Summer break and will be taken up by a future class to develop into a completed game.

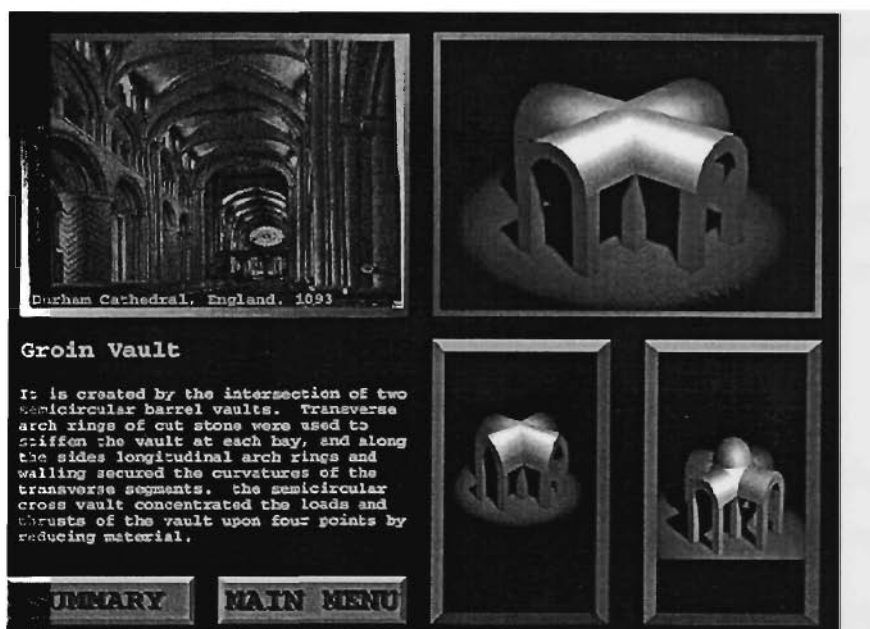


Figure 6-28: Page from the final Showcase presentation

Figure 6-28 shows a page from the completed Showcase program. It illustrates a "groin vault" with a photograph of Durham Cathedral on the left and a stylized image on the right. Below this are two possible

“developments” from this shape – a vaulted arch (L) and a dome (R). The user selects one to see which is the correct morph.

PROBLEMS

The Morphing group functioned well as a team and their only problems with coordination were caused by the difficulty of the project itself, not with the way the group was organized. The two main problems the group faced were:

CONCEPTUAL

The ideas which they were dealing with were extremely complex. How can one tell whether one style of roof shape could validly transform into another style? Historical research can only go so far and the project involved them in studying theoretical issues in architecture which they had never encountered. It is doubtful that this was an intended outcome of the project, so it was a learning experience for students and staff alike.

COMPUTING

At the beginning the students thought that the “morph” command in the 3D Studio menu would do it all for them. All they would need to do was provide a beginning and end image. Morphing is rather more complicated:

1. The two images (start and end) must be constructed so that they are “possible” – i.e. of equivalent dimensions, scale and rendering
2. The morphing “points” are then defined. A point on the start frame must morph to the equivalent point on the end frame. For a “realistic” morph it may be necessary to define 100 or more points
3. The points then become the apexes of triangles, within each of which the program will conduct the transformation. The more triangles the smoother the morph, but the longer the rendering will take.

4. Decide on the number of frames and the frame speed (time) of the animation sequence and render the images.
5. Evaluate the quality and validity of the morph and make alterations to points and triangles as necessary. Steps 3-4-5 are repeated until a satisfactory result is obtained.

The project also involved them in transferring files between three programs:

1. The original structure design was produced using AutoCAD
2. Morphing, rendering and animation were carried out with 3D Studio
3. The sequence was then incorporated into a Showcase presentation

The group overcame all of these problems only to be frustrated on the final day by the system crash.

CONCLUSIONS

In addition to the considerable creative achievements detailed here, the four case studies presented in this chapter illustrate a number of common problems and concerns, for example:

- the conceptual demands of a sophisticated computing environment in which a variety of applications, file types and file storage systems must be manipulated to produce the final product;
- the considerable research and creative skills required to solve and present a complex structural problem within a restricted time frame;
- the uneven distribution of computing skills and the problems of acquiring skills "on the fly";
- the importance of interpersonal, organizational and time-management skills when working in a group project environment;

- the uncertainty of being dependent upon equipment which, if (when) it fails, can destroy the entire project.

The ways in which students interacted with these issues will be examined in the following chapter.

Chapter 7

Cognitions

Summary: This chapter describes some of the ways in which students coped with the computing, conceptual and creative demands of the project work described in Chapter 6. It examines two aspects in particular: (a) metacognition, or students' conscious thoughts about their own learning: their emotional responses, self- and task-knowledge, cognitive self-management, and responses to the learning environment and teaching methods; and (b) distributed cognitions, or the ways in which students were able to share the cognitive load both across the group and with the computer.

METACOGNITION

In a defining article in *American Psychologist*, John H. Flavell described metacognition in the following terms:

I believe that the monitoring of a wide variety of cognitive enterprises occurs through the actions and interactions of four classes of phenomena: (a) *metacognitive knowledge*, (b) *metacognitive experiences*, (c) *goals (or tasks)*, and (d) *actions (or strategies)*. Metacognitive knowledge is that segment of your ... stored world knowledge which has to do with people as cognitive creatures... Metacognitive experiences are any conscious cognitive or affective experiences that accompany and pertain to any intellectual enterprise... Goals (or tasks) refer to the objectives of a cognitive enterprise. Actions (or strategies) refer to the cognitions or other behaviours employed to achieve them. (Flavell, 1979 p.907)

An ERIC search on "metacognition/metacognitive" returned over 2,500 documents, indicating that the issue appears to have become an

accepted element of USA curricula; perhaps an outcome of the widespread debate about constructivist theories of learning in that country (Bransford, 1986; Dharmadasa, 1994; Dunlap & Grabinger, 1996; Schraw, 1995; Thiede & Dunlosky, 1994; Wolters, 1990). This is not the case in Hong Kong, where a conservative educational tradition ensures that domain knowledge remains the primary focus of the curriculum. Any metacognitive knowledge displayed in the interviews with the students in this study is the result of independent reflection rather than teaching.

The core of this chapter is students' statements about learning and knowing, in other words their metacognitive knowledge, experiences, goals and strategies. It covers a wide canvas, from attitudinal factors which affect learning, through to evidence of a sophisticated level of task-knowledge and self-knowledge, which includes both cognizance of what they know as well as of what they don't know.

EVIDENCE FOR METACOGNITION

According to Barry Will, the lecturer in charge, the Building Systems course was primarily about "developing an appreciation of the interacting systems which make up a building", but it had an equally important second dimension – the employment of computer modelling techniques as a means of structuring and presenting knowledge. The difficulty of reconciling the twin goals of learning about building systems and mastering the computing environment was a major issue in students' statements about their cognitive processes and is summed up concisely by Alice:

ALICE: Most of us think that it is very difficult to think in front of the computer.

This was the dilemma faced by many of the students as they were forced to adjust modes of working and learning acquired over 5 years of traditional architecture study to the considerable challenges of the SGI

environment. As the interviews progressed over the term an increasing proportion of text units were devoted to the question of human-computer interaction. The following quotation is from an interview in which Alice had been invited to talk about how the computer might assist her to conceptualize a building structure. Alice was one of the students who remained a "computer-sceptic" to the end, nevertheless she had very clear ideas about her relationship to the computer:

ALICE: I just treat the computer as a machine. I am not a programmer, I don't know how to create a function for it, therefore I can only use the functions which are available for me. In other words, I will just perform those tasks it allows me to do. I think for me if I want to use the computer to do the design, I will have a preliminary idea about the spatial and architectural forms and then go to the computer and it might help to do the design in some way, because it is more easy to move and do stuff like that. (However) I think for the preliminary decisions ... the thinking mind and the paper is much faster.

Joan, another computer-sceptic, was also concerned about the requirement to divide her thinking process in order to produce on a computer what she considered could be better achieved with traditional media

JOAN: Say if the design work is in the early stage and you want to use the computer to do the sketch of the design, then it will have lots of limitations and say, half of your brain is being used for the thinking process on how to plan your work already, so it will be faster if I can use my pen to draw them

Joan's concern clearly mirrors Minsky's (1986) "**Recursion Principle**: When a problem splits into smaller parts, then unless one can apply the mind's full power to each subjob, one's intellect will get dispersed and leave less cleverness for each new task." (p. 161)

These two statements highlight two of the cognition issues which recur in different forms in this chapter

- in addition to domain task-knowledge (architectural and building systems), the course required students to develop a sophisticated level of task-knowledge in computing, which some considered to be an unreasonable additional burden.
- the unfamiliarity of the computing environment provoked emotional responses – in some cases a degree of antagonism or defensiveness – which affected students' attitudes and motivation

The chapter examines what students had to say about their learning and working methods. Continuing the methodology of this project, the categories have been developed using a data-driven approach rather than relying upon existing models of metacognition. The result, however, is not inconsistent with Flavell's classification. The initial categorization of Node 5: "Cognition" was treated in detail in Chapter 5. For the current chapter, the relevant indexing nodes were searched, NUD•IST Reports were produced based on cross-references to project group and some profile categories. There was a great deal of overlap in the indexing which resulted in a certain amount of redundancy. A process of data-reduction followed, with the aim of distilling the reports down to a workable set of clearly-identifiable categories, with quotations from the students which encapsulated the class of metacognitive awareness.

AFFECTIVE FACTORS

This category indexes statements which include visceral (or "gut-feeling") responses to the learning experience, in particular to the computing environment, to the collaborative learning style and to the pedagogical style of the course. Almost all the students made statements about their feelings towards the course at some stage, so the remarks which follow should not be attributed only to that speaker. Unless indicated otherwise,

the criteria for inclusion has been that the statement is representative of a commonly-held belief.

"I hate computers"

Five of the female members of the class often expressed strongly antagonistic attitudes towards the computing environment. (On the surface, this might appear to be a gender issue, however the two other women did not express such feelings and two of the five later went on to become skillful AutoCAD operators.) The hostility was due to a variety of factors. For Alice and Bonita it was expressed as a concern about not being in control of the situation.

ALICE: I am not very keen on it. I tried to pull myself away from the computer. Maybe I am not good in the computer so I don't want it to control me. I want to control it.

BONITA: I don't like the computer personally. I found that it is quite complicated when I use it and you don't know where it goes wrong. Sometimes, you've done a minor mistake but you don't know what is it. So, I hate it.

For Joan and Shirley, the reason for the antagonism was less clearly articulated, but just as deep:

JOAN: I still don't like computer. As I get to know more, I find it useful... Well, it depends how you use it and how well you know the program.

IAN: Do you think you will use computers in the future project work?

SHIRLEY: Not much.

IAN: You are not very happy with computers?

SHIRLEY: Obviously.

Christina had two complaints about the computer environment: concern that such intensive and detailed work might damage her health,

and boredom with the repetitive tasks she associated with computing. It made her feel more like a “factory worker” than an architect:

CHRISTINA: I don't like to use the computer tools because it's hard for our eyes and health.

... If you have eight elements, every one of them has about fifteen components. Eventually, we need to do it over a hundred times...I think I will die if you want me to work in a factory. I won't disagree that it is good to learn some new software but it is waste of time of being a technician.

“I'm ambivalent about computers...”

A larger proportion of students expressed concerns about the way in which their lack of computing skill might affect the quality of their work, or the ways in which the computing environment made them change their working methods. Fai sees himself as an unwilling conscript, whose motivation for learning software is purely extrinsic.

FAI: Some of us are quite keen on computer, it would become very effective for them to do it. (But for the rest of us) there is nothing that would drive us to learn this software (apart from the course)

In Frankie's eyes it is a matter of personality. He'd like to have better computing skills, but does not see himself in the computer super-hero mould!

FRANKIE: Some of my classmates could be a "COMPUTER MAN", I don't want myself to be a "COMPUTER MAN", but I would like to keep myself closely in contact with computers. I would still like to draw by hand and keep on working that way.

Howard, who produced all of the morphing animations, would probably fit Frankie's definition of a “Computer Man”, but he too was ambivalent about the usefulness of the work he had done.

HOWARD: I believe that the computer is very useful. But for this project, this is just another little (step forward). It is a bit of a waste of time. (Though) generally speaking, I prefer to use the computer.

William, at the opposite end of the computer-skills spectrum to Howard, displayed an optimistic attitude:

WILL: Actually, if I have the chance to build up my own ability in the use of computer, of course it will be an advantage. It's always better to expand our knowledge. So, I will love to.

"I enjoy group work"

The cognitive issues raised by working in groups are treated in more detail in DISTRIBUTED COGNITIONS, below, but the group environment was also an issue with emotional connections. At the beginning, the groups made up of HKU graduates who had known one-another for a long time appeared to function more smoothly than those with overseas graduates; but in the end it depended very much upon whether the members were compatible and willing to compromise:

MAN: I enjoy it because I am in this group. I think it depends on who are my group members. If I were grouped with somebody who is difficult to get along with, then I don't think I would enjoy it. However, it's all right overall.

CHRISTINA: I have also worked on another group project this year. (In a different course) Unfortunately it did not work out that well because, I think the most important reason was we didn't get along. I was amazed that I was in a group (Curtain Wall) that I can work with and we can compromise. That is the best we can do. We compromise with each other.

"Did you enjoy the course?"

Students had a great deal to say about the BS1 course, and the critical issues are taken up in more detail under PEDAGOGY. The operative word in this section is "enjoy", as students also expressed personal feelings such as

"pessimism", "enjoyment", "frustration", "satisfaction", "suffering", etc. which affected their views about the value of what they were doing.

Christina and Frankie admit (albeit grudgingly) to having enjoyed the experience. Christina regrets that she couldn't take out her frustrations about the equipment in a more physical way:

CHRISTINA: Yea... I don't know it sounds a bit pessimistic, but I guess I did enjoy a bit of it. I must have. I mean I didn't enjoy the part where we lost the files or... I guess it's a part of learning but it's so frustrating that you couldn't hit it. You couldn't yell at it. It wasn't responsive in that way.

FRANKIE: I agree that we need to spend a lot of time in doing these things. I just try not to be so negative. I think we can still learn some from the project.

Desmond, Howard and Mo, all skilled computer users, also went through "black" periods. Desmond would have liked to be able to produce higher-quality work on the *dau-gung* models but was frustrated by the limitations of the laboratory and time constraints of the course:

DESMOND: Basically, it's not the things we can't do, but just (things we are) not very satisfied with - for the results of it. As I've said before, there are some features that are so complicated that for the computer to generate the image. I can't get any satisfaction from the result at all. Perhaps, I would feel more satisfaction with animation, but not with modelling.

Howard enjoyed "playing with computers" to produce the morphing animations, but felt guilty that he was just having fun when he should have been learning more relevant skills.

HOWARD: I think I've learned something in this course, but the things I've learned are not very relevant to my career. . I like to play with computers, but as study goes I don't greatly enjoy it.

And Mo, who produced the painstakingly detailed animations of the lift system and curtain wall construction, felt he had also missed out on something:

MO: Enjoy... Not really. Because so much time has been spent on the computer work and not much on the actual building system. And so much time on how to use the computer, so I don't think I have achieved the purpose of the course.

On the other hand Ronald and William, two of the less-skilled computer users, enjoyed the learning experience and felt a great deal of satisfaction:

RONALD: I don't know much at the beginning, now I learnt a bit more and I feel good about it. I don't really think that our work are out of line with out expectations.

WILL: Maybe you need to suffer a bit at the beginning, that's all. I think it's the chance for you to learn.

SELF-KNOWLEDGE

How do students see themselves as learning most effectively: from books and lectures, from working in a team, from trial and error, from demonstration? Students were asked to talk about their *metacognitive monitoring* as they went about the task of learning new skills.

Learning computing

In the BS1 course there was no formal instruction on computer software – it was loaded into the system and students were expected to learn it as they needed it. It was a “sink or swim” environment and the students often had to learn very quickly how to master complex computer operations such as rendering, animation and hyperlinking. For Ronald there was a question of equity – in his eyes the more computer-skilled had an advantage:

RONALD: Somebody who doesn't know how to use the system would rely on those who know it. So, the one who is more familiar with the system will learn faster than the others because they need to do much more work. Those who are not really keen on computer would not like to do it anyway. And it takes much more time for them to learn.

Even for highly-skilled students such as Desmond, the problems posed by the projects (in this case animating the *dau-gung*) could be beyond their ability.

DESMOND I don't know what is going wrong at the moment.

WAI-LING: Do you think that you possesses the skills to solve the problem?

DESMOND: Well, the basic level, but not enough. I can't really do this by myself.

WAI-LING: If you think that you haven't got enough skills, how will you go about it?

DESMOND: I will learn it through trial and error. Perhaps I will ask people around as well.

For students needing to learn basic applications, there were three alternatives: self-study, using the manuals; asking for help from classmates and tutors; or trial and error.

ALICE: I think reading the manuals and books is the best way for us to learn. However, it takes a long time to finish the reading of them. As a result, we normally would turn out ask the other classmates to see whether they know how to do it or not? Once they taught us some techniques, we started to try it out. If we have problems again, we will ask people again. Or we will ask the technicians here too.

For most, the issue was time. There was no time to learn application programs in detail and students were forced to pick up skills "on the fly". Christina was typical in preferring to learn the basic operation by observing a skilled operator and then trying it for herself.

CHRISTINA: I think I prefer watching someone do it first. I guess I'm visual. Watching it, and then I want to try it out. I find listening, sitting in the lecture, very hard. Boring...But I think I still prefer to have a Manual. Just in case.

Another means of acquiring skills was through asking the laboratory technician and two research assistants for help, although they all had their own agendas and were not prepared to teach application programs. Fai values the fact that the technician (Raymond) did not just do the operation for him (e.g. transfer files by ftp) but insisted the students learn it themselves:

FAI: Sometimes, we tend to learn it from talking to others and watching what they are doing. However, the assistance in the technical side would be like we don't know how to ftp the files, then (the technician) will actually do it for you. Software like Showcase is not that often for us to ask them for help. They suggest you to learn it first instead of telling you how to do it. I think it is quite a good method.

Han's experience of learning by trial and error is also typical – students developed a *just-in-time*¹ approach to software, picking and choosing between applications on the advice of classmates and tutors and learning only those operations which were relevant to their immediate needs.

HAN: My computing background is just fair. I need to remember the commands by heart. Sometimes, the case might be similar but I don't understand the concepts at all. In that case, it will take more time for the staff to explain it to me. I think it's hard work for them. When I forgot something, I need to go back to the staff and ask them about it again. I like to work by trial and error. Rather than look at the Manual I prefer to use the Help or use the icons in the computer directly.

¹ An industrial management practice whereby stock is brought in only when it is required.

With the “indexical”² graphic user interface having largely replaced text-entry or command file operations, and on-line Help having replaced the manual, students now have an expectation that they should be able to learn a new computer program by trial and error, rather than by studying a comprehensive manual or working through tutorials. This is the basis on which they classify a program as “user-friendly” or not.

LEUNG: I've obtained my AutoCAD and 3D Studio knowledge from my own learning. I sat in front of the computer and tried to learn it. I didn't refer to any manuals the first time. I found that one of the most efficient ways for us to learn the software and the way how to operate the computer is by trial and error. I try to understand what will happen when I press certain key. It will give you the image of how the software works. Then you can refer to the manual and then try to find out what is that message refers to and try to understand the message.

“My preferred learning style...”

Students were asked about the way that they preferred to learn – some, like Alice and Waiman, valued the way in which formal lectures and notes provided a structure; deep approach learners, like Han and Christina, saw value in combining formal presentation with independent study, workshops and collaborative work.

HAN: I do like workshop types of learning. This means doing research or having a project. We should (also) have lectures or something – notes – to have more background of the project before we go to the workshop. (I like to) work practically on a project that we have learned about (in lectures). In other classes we just have lectures and then we go to the examination, but when the examination happens there is not any satisfaction to us.

² In the language of semiotics (Peirce, 1931-1958; Wollen, 1972), the small representational images of the common GUI are more correctly described as “indexical” rather than “iconic”.

Students tended to describe their preferred learning style as either *verbal* (independent, book study), *visual* (images, diagrams, multimedia) or *practical* (hands-on). Howard, below, believes that his learning style has undergone a gradual change over time, marked by what he describes as a diminishing "attention span":

HOWARD: It depends upon the kind of thing I want to learn and the time that is available. If I remember that in the secondary schools it's ... just reading and words and maybe somebody doesn't understand what is studied, but they just remember it. But I think that as I become older my attention span is shorter, so that this kind of learning - attending lectures - is quite demanding for me. So learning by multimedia is more appropriate for (now).

IAN: So you think you've moved from being primarily a verbal person, who reads, to being a more visual learner?

HOWARD: Yes, because for more recent learning it can keep my interest.

What Howard really means, of course, is that he no longer has the patience to sit through the kind of one-way instruction he received at school and now wants to take responsibility for his own learning. There is nothing deficient in Howard's "attention span" when he is working on something that interests him.

Architects, on the whole, find words inadequate to express their ideas, whether it be about forms, shapes and volumes or about more concrete matters such as engineering specifications or interior design.

YIN: We need to visualize the object three dimensionally. We can't simply just understand or decide something by means of texts or some images. We need to see an object, a concrete thing.

Talk to an architect for more than a few minutes and it is likely that pencil will have been produced to draw a diagram of the conversation. For Joan, it is not just a matter of Cantonese or English, language is inadequate

to express what she wants to learn or say. She finds it difficult to conceptualize from verbal information and has developed a strategy of using drawings and models to structure knowledge.

JOAN: If I work on a design, for example, I would tend to build the model and see what actually I am doing. I can visualize by doing this. In order to communicate, I need to have a physical thing, because verbally I cannot describe what it is. And by doing a model, that helps me to see it as it is here, what I think it is and whether I am right. And also it is easier to communicate with others by using a model or simple diagrams (so) when everyone looks at it they know what I am trying to do.

Lun expresses essentially the same idea. He prefers to visualize concepts as diagrams and it is in the act of producing the structural representation that understanding occurs.

LUN: I think the diagrammatic method is much better to me, but it is a problem if the diagram has been prepared by other people. Actually those people have analyzed the data, the text and all of this and tried to represent it by a diagram, so that in this stage although I can more easily understand some of the information, it is second-hand information. This is the problem. I would prefer to visualize the diagram myself. Much better to me.

For most of the students, active engagement in the learning task – learning by doing – is the preferred way of approaching study.

MO: I think I prefer learning by doing something. Actually the learning process I like learn through working and doing.

RONALD: I like to learn by trial and error. I will get some basic instruction and then try to run the computer myself.

TASK-KNOWLEDGE

This is defined as knowledge of the cognitive processes required to complete the task and in the BS1 course this involved acquiring both computing skills and domain knowledge. The first two sections below examine the task knowledge which students feel they need to acquire; in the third section, students discuss whether these learning objectives have been realised.

Computing tasks

The first problem the students faced was the number of different software programs they needed to learn in order to complete the assignment.

MO: We should know the basic software such as 3D Studio which performs the animation for you, AutoCAD for the geometry and some linking tools such as Animator Pro too... we need to know other morphing programs as well.

CHRISTINA: At first I thought it was impossible and too difficult for us to do this kind of animation, but now it seems much easier. However, I still need to learn 3D Studio and Showcase etc.

The greatest problems, however, concerned the transfer of files from one program to another, and within this category there were a range of conceptual issues which needed to be understood. In projects such as the Temple, where each student had been working independently on a section of the entire project, they needed to combine the different AutoCAD files into one.

ALICE: As you see here, we've loaded the image already, but we don't know how to merge the columns and the roof together. So, we need to learn it in all these different stages. Its a bit hard though.

Producing the *dau-gung* involved beginning the drawing in AutoCAD to produce the individual 3D elements from the measured 2D

drawings. Much of this was done in the PC lab as most students were more familiar with the PC version of AutoCAD. The files then needed to be transferred to the SGI environment as the PCs were not powerful enough to deal with the complex curves and multiple interlocking shapes. It was also necessary to move the files back and forth between AutoCAD (the common format for the Temple) and 3D Studio, which was less precise but more flexible, in order to check the assembly, to render the model and develop the animation.

DESMOND: For example this one (POINTS TO THE *DAU-GUNG*), you need to draw it in AutoCAD. You need to know how to create a 3D object in AutoCAD. Then we need to transfer it from AutoCAD to SGI. It will then involve some more computer operations. Shouldn't be that difficult. I tend to use PCs more often, so I have some difficulties now. Besides these two systems, we need to use 3D Studio to check whether there's anything wrong in the objects we created in AutoCAD.

The Temple project was mainly confined to AutoCAD for the design and 3D Studio for rendering, checking and animation. The process of moving between them is not difficult as the two programs use compatible file formats. However, other projects, which required animation effects in Showcase, produced greater file transfer problems:

FAI: (CURTAIN WALL GROUP) We first need to know how to run AutoCAD and then create a 3D model by drawing a 2D shape of it. After that, we need to get the image from AutoCAD to 3DStudio and then we can perform the animation and some other visual effects from there.

Fai was underestimating the complexity of the operation, as animation required up to four operations in different application programs. Man (Maintenance) is very aware of his current lack of knowledge and explains the computer skills the group will need to master in order to produce the planned animation sequences:

MAN: There are a lot of things we need to learn. We know very little at the moment. The skill we have is kind of surface skill, not too much details at all... So far, we can do two dimensional images in Showcase. What we are working on at the moment is how to create a three dimensional interactive image in the layout of the Showcase, so that the user can read the information and also play around with the model as well. We are learning how to do it now. This time we are using a different method to create the animation. We need to use Movie Player so we can't use the PC software to create it and then load it to Showcase. We need to create each single frame from the PC. For example, if we have two hundred frames for the animation, we need to copy two hundred frames to the Movie Player so that the Movie Player can merge them together. Therefore, we can fit it onto the Showcase and you can design exactly when do you want it to be displayed on the screen and when you want to finish the animation too.

How were they to learn these techniques? None of the technical staff or teachers could advise them. The only people with any experience of producing animation were Waycal, a Ph.D. student and research assistant, who had developed a comparatively simple sequence for the Temple Tutor; a technician in the Centre for Media Resources who was using 3D Studio to create animated titles for a video program; and a technician in the Department of Computer Engineering who had been involved in making a 3D animated model of the Main Building for a promotional video. Apart from that there were some demonstration programs which came with the SGI software and some off-air video programs about computer animation in the film industry. Mo, who eventually produced the curtain wall animations, exploited all these resources:

MO: I don't know. I really don't know what to do. We can't really ask people all the time. There are so many problems. This kind of system and software is really big. There are all

sort of problem will occur any time. Its not enough to know one or two things only. For example when I create this animation, I need to know how to create the image. Then, I need to know how to convert the image from PC to SGI. After, I need to change its format from SGI, then all the images will be linked up and produce the movie. I think I am lucky because I've heard people talk about it before, so I know I can do it in this way. Otherwise, I wouldn't know how to start it. I wouldn't even know this could be done. The main thing is I don't know what kind of question should I ask (of the tutors). Even though you ask them, they wouldn't know what you want to do. Or perhaps it is so complicated that others would not like to tell you at all.

Domain tasks

The objective of all four projects was to explain structural principles to a lay audience: how a certain type of building or system fitted together and operated or developed over time. This involved the students first developing a thorough knowledge of these systems.

The most complex project in terms of domain knowledge was the Temple, which first required wide-ranging research into both the structural and religious principles underlying Tang dynasty temples. This required integrating computing task-knowledge with domain knowledge. In other words reconciling the advice from Waycal and the other tutors on methods of producing these types of 3D models with the display requirements of the client.

DESMOND: People like Matchy and Waycal can provide some more technical information. They can tell us how we can do a specific task, then we will think about the way to do it. However, the design and functionality of the project will be decided by us since we are the ones who know the use of the model, Waycal and Matchy would not know it at all. Therefore, we need to collect the information from Barry and the users in

order to obtain enough requirements for us to create and design the model.

The most complex aspect was the interlocking *dau-gung*, or bracket system, which has the function of spreading the load of the temple roof onto the supporting columns. This involved first learning to “read” the 2D drawings, and then producing accurate working models:

BONITA: We have to comprehend the 2D drawing first ourselves in order to draw it into 3D model and this is what we have to learn and then try to convey this message to a third person who is looking at it on the computer. How the bracket is assembled. So we are learning something about the bracket system and something about the presentation.

The *dau-gung* varied in complexity from small, comparatively simple structures to corner brackets 3 metres square made up of 25 pieces. Desmond explained how they needed to reconcile the need to demonstrate the details of construction (the interconnecting rods) with the limits of the screen resolution once the *dau-gung* is incorporated into the building.

DESMOND: This one is less complicated. We have another one which has a hole in the middle of the *dau-gung* where we need to put a rod inside so that we can connect one “*dau-gung*” to another. If you don't put the rod there, then, there are not enough points for us to create the hole there. Like the one I just showed you, it was so small and tiny. Even though we created the hole there, you can't see it anyway. However, we can put it in this one. We need to use this model somewhere else, so we need to emphasize the way it can be fitted to another part of the model.

The *dau-gung* group also needed to be conscious of where their work fitted into the temple structure as a whole. This future requirement necessitated the development of a reference system to which everything could be related:

YIN: Basically we had a grid line to coordinate all the dimensions. Maybe there's a cross... The intersection of the grid line is the centre point of the column, which is also the centre for the *dau-gung*. If all of us are doing it correctly there will be no problem. But maybe there are some minor errors so that we have to check when we reassemble the thing. I think it's not a great problem because everything has its own dimension and grid line to control.

The aim was that all participants would acquire detailed "micro-knowledge" of the particular temple components they created and "macro-knowledge" of the temple structure as a whole, but the complexity of the project and the time constraints meant that only the first aim was achieved.

BONITA: Because of the nature of our project we have spent most of the time in sorting out the bracket system - how they are assembled. So we couldn't spend too much time on the presentation, or any new idea about bracket system or new idea about architecture.

LEUNG: I want to know how the brackets work - the way they assembled it - and also the animation to show the sequence of construction - which member is on top of which member.
(However) at the moment, I don't have any chance to understand. You see, I did the research work first.

All groups did research: consulting books and speaking to experts. Ultimately, however, the most valuable domain knowledge was acquired through constructing the models. It was a process of trial and error, visualization of the structure and simulation of the system in action.

IAN: Where did you get that information from?

CHRISTINA: Basically from the shop drawings and seeing the details and actions and...

IAN: So you're figuring it out from what you already know?

CHRISTINA: Yes, like a puzzle.

IAN: There was no textbook to refer to?

CHRISTINA: Actually no. It was pulling things apart and working out what would go together and come out first. Sometimes Barry would say to us, no that doesn't come out first - this does.

In the example below, Han explains how the Morphing group worked through the problem of why a slab roof could not morph directly into a groin (double) vault (see Figures 6-21 and 6-22). This was information they could probably have discovered through detailed research into the history of structures, but it is unlikely they would have comprehended the problem as vividly as they do now from trying to simulate it on the computer.

HAN: We tried to guess how it morphs from the single to the double (shape). Howard did the morphing... We didn't think it was a problem, but when he did the morphing we knew this was not the one I guessed, because the flat slab moved outwards and then it morphed into the vault. I realized it is wrong because the length of the vault will be very small and then go along like this... and all the roof will vault. (So it's impossible for) the flat roof to suddenly become a vault. So we discovered that there's lots of morphing ideas around from one shape into the others, so we all sat together and discussed how the single morphs to the double vault.

Learning outcomes

The third aspect of task-knowledge concerns students' views on how well their learning objectives had been realised. Howard, for example sees three learning outcomes being achieved: learning new software, project management and communication.

HOWARD: First of all I did a project where I needed to learn 3D Studio, the morphing part of 3D Studio. How to divide the job to different people with different skills. Or for the last stage, we have learnt how to communicate with the user. That's what I've learned in this exercise.

For the Temple group there were two achievements: the development of CAD skills through a fascinating project; and also a first experience in real client relationships, because they had to liaise constantly with the nuns and the temple architects in order to produce a model to satisfy a brief.

RONALD: At the beginning I was not familiar with AutoCAD, then I learned how to draw some models with it. After that, I learned how to use 3D Studio and also how to run it on the SGI environment as well. Although, there is still a lot I do not understand, as the project becomes more and more mature, I start to learn a lot more. Moreover, since we need to contact and communicate with the people in the temple and outside, I've learnt how to discuss with them and get the requirements and specifications out of them.

For Ho-yin there was a real sense of achievement in unraveling the complexities of the *dau-gung*, something he feels that he did by using his own resources. He became so engaged in the project that after the computer crash he worked on over the Summer vacation to complete the job.

YIN: For myself I really did learn something very new to me - because when we got the hard copy from the nun it was very strange to me and very new to me. Even though I am Chinese and I may know something about *dau-gung* but all the details, all the dimensions of the components were new to me. Throughout the process I had to read the drawings and to read some (historical) documents. After that I thought I understood the details of the components but actually when I tried to draw them three-dimensionally in the computer I realize I don't quite understand... I had to work it out by myself until I fully understand what it is. You remember our group had a disaster. Another classmate and I took a job during the Summer vacation to try to recover all the files and do some new things. And we are dealing with the same things, so that now

both of us have similar understanding of the *dau-gung* and the whole project.

Yet for others, there was a feeling of missing out – of not having learned as much as they could have. Mo, who spent all of his time developing a set of complex animations, felt that he learned very little about the subject of the course – building systems:

MO: (Too) much time has been contributed to the computer work and not much on the actual building system... so I don't think I have achieved the purpose of the course.

For Christina, who lead the Curtain Wall group, the problem was that she would have liked to have been involved in all the projects. She partly achieved her aim by working over the Summer (with Ho-yin, Joan and Han) to resurrect the temple project after the crash.

CHRISTINA: I think, depending on which project you worked on, you learned more or less. I worked on Curtain Wall so I knew a bit more about Curtain wall... Actually I know a lot more about Curtain Wall than other people, but I don't know anything about Maintenance, or Temples. I think we concentrated on one thing very seriously, but I don't think many of us learned much about what the others were doing. I would have liked to learn about other things. I just felt I wanted to learn more about every little thing but I didn't have time.

COGNITIVE SELF-MANAGEMENT

Cognitive self-management is defined by Tenysson (1994) as

“Readjustment of behaviour or thinking in response to feedback” (p.18). It also means the success with which students carry through on the learning strategies they set themselves; the closeness of fit between what they say they will do and what they actually do. Students were asked how they go about learning? What were the most important strategies?

For students with a deep approach to learning, the motivation to learn is intrinsic and the approach to managing their learning is related to

their particular agendas. For Christina, the team leader of the Curtain Wall group, communication and time management are the most important skills to acquire and the evidence was that she worked hard on sharpening them throughout the term.

CHRISTINA: The most important skill (is) the way how to work with people at a professional level. Say, with the other leaders, classmates and professors. Also, the way to manage the time and learning the computer aspects as well.

For Han, who had the highest SPQ scores on deep-achieving approach, time management was an increasingly important factor. She was finding it difficult to reconcile her preference for discovering things for herself with the deadlines imposed by the project.

HAN: Every time we are in a rush when we have the problem, so it would be nice if I can get back the answer directly. However, I think it would be nice too if they can give us the hints and direct us where should we look for the problem. Another way for us to find out the solution is from reading. Well, the staff know the Showcase in and out, but they haven't got the responsibility to lead your thinking. They have no duty to train our independent thinking.

Joan was struggling with ways to balance her innately curious nature with the need to deliver on time and to communicate her ideas coherently. In BS1 she had begun to realize that by using models and diagrams she could be as "articulate" as the next person – a strategy she carried through into the fifth year where she scored high marks and graduated in the top 25%

JOAN: For me, it is difficult to put things in a very organized way, cause I am always jumping from one area to another but then for me it was always here but how to convey the message, by model or some diagrams.

For Wai, the top student in the year, the problem was exactly the opposite: because he was such a good communicator his classmates expected him to do all the work. His strategy was to make sure that everyone did his fair share and that everyone learned something from the experience:

WAI: At the beginning, the group members expected me to do more stuff. But I made it very clear that we are going to work together as a whole team instead of shifting the job to one person because I think that we all need to learn about it throughout the whole process. So, I made this point very clear at the very beginning. So, I stopped giving my opinion all the time and let them start to think about it - instead of all the time me doing the talking.

For others the motivation for acquiring new skills is more extrinsic: they learned because the course required it. But as the cognitive load increased over time, learning new skills became proportionally more difficult to achieve.

FAI: ... We will also consider whether his requirement is reasonable or not. But I think at the end we normally need to do it anyway.... When I was in my first and second year, it was not so difficult to learn it. However, once we were in our third year, the course was so tense that we could hardly do any practice with this kind of software and I am not particular keen on computer anyway,

Some saw acquiring computer skills as the equivalent to learning a musical instrument – it takes dedication and practice:

LEUNG: Its not very difficult but you've got to spend more time in it and keep using it. Otherwise, you will probably forget everything.

RONALD: Well, if you want to improve your skill. The first thing you need to do is to find out the cause of the problem. Once you've got that, you can ask people around you or find out

the answers from the books. The most important part is you are willing to spend time on it.

For those who entered the course with very low computer skills or who were uninterested in computing the most effective strategy was to rely on the assistance of classmates or the laboratory assistants and tutors:

SHIRLEY: I will ask my classmates or try it out by myself. I will normally try it out to see whether I understand it or not. If I still don't understand it, I will ask the lab assistant for help.

WAIMAN: No, I think I will ask people first. If I don't know how to do it, I won't try it by myself but I will ask people to teach me. You know, it is time-consuming for you to find out how to do it from the book. It would be quicker for us to ask those who knew the system.

WILL: Some of my friends will help me and I will consult them if I encounter any problems. Yes, that's right. I will do the trial and error first. If I found that I can't do it anymore, I will ask my friends.

MAN: I will ask people first. Once they tell me what is interesting, I will then get into the system and try it out by myself... If I encounter something more difficult, I will then ask the demonstrator.

PEDAGOGY

What were students' reflections on the PBL approach of the BS1 course as a learning experience? For the Hong Kong students in particular it was difficult to make comparisons with any other style of teaching. The person with the most opinions on this subject was Christina, who had taken her first degree in Canada and was generally critical of the Hong Kong teaching methods which she saw as encouraging a surface approach based on rote memorization and a focus on assessment.

Individual differences

CHRISTINA: In Hong Kong if you can memorize it well then you do OK. This is what I don't really agree with. In terms of learning, you should be able to digest the information they give you and then apply it to something else. They shouldn't just require you to have a good memory. It doesn't mean anything after the exams if you can memorize it and then forget everything. A lot of students learn differently. Under the same teaching methods, some of the students might be interested in your teaching but others might be uninterested in it. So, you are only teaching half of the people. Say you tell students the way to do it and then tell them to go and do it. Some students don't like this - some students like to be shown exactly how to do it. But others like to be left alone and they will learn to do it on their own. I think you should cater for both of these needs. At least a percentage of the students should be allowed to learn at their own pace and in their own way.

Learner-centred environment

At the beginning students found the most challenging and exciting aspect of the problem-based course was the experience of being in control of their own learning: to set their own agendas and time frames, to work at their own pace and devise their own methods.

FAI: I think those who participate in the project would feel much more interested when they are creating the project.

For Joan, who valued her individuality and her personal vision, the challenge was to find a way of keeping to an agenda within this less structured environment:

JOAN: I have to learn a different way of thinking. Some people start from very basic research or from drawing. Some people just come up with their solutions from their past experiences or whatever. Some students find the computer one way of designing things and making presentations while I found other

ways more comfortable, like writing small notes and putting these notes together to keep a record of thinking, and then by looking back to these notes to find what has been missed out.

By the mid-point it became clear even to Christina that such an approach involved considerably more self-discipline than a conventional lecture-workshop course:

CHRISTINA: I think I like team work and using the problem-based method, but socially speaking it was very hard. We were in the labs in the early morning and at night. And then I also realised how powerful it could be too. It was the first time for me to use such a powerful computer.

BONITA: Sometimes when we are not too tired or occupied by other jobs as well at the same time this way of working is very enjoyable. But when there are a number of jobs to be done at one time then we have much more to do in this project than we can enjoy.

Peer teaching

Barry Will values peer teaching and regards it as one of the unique aspects of the BS1 course. He has a strong belief in the educational value of students working together to solve a common problem as this is a realistic reflection of work practice in a commercial architectural firm. For students like Christina, educated in the North American tradition, this approach opens exciting possibilities:

CHRISTINA: Learning should be fun. It shouldn't be like just reading from the books. I think it should be more group related. Like cooperation in terms of learning from each other, not only from teachers. You can learn it from peers or probably other people like maybe not only from the classroom but from outside. I like the idea of learning on the job, like a workman. That is very important.

But for other students, brought up in a tradition of externally imposed criteria which are examined for assessment, the open-ended approach to learning can be unsettling. One of Mo's constant complaints was that he was not told what to do and felt that he never understood what the unit was about. For Mo, peer teaching means the blind leading the blind. How can you learn something if you don't know what questions to ask?

MO: When we learn the software, we don't really need to study hard to learn the commands, we should know what sort of facilities we have so that we can do things according to the functionality. (But) sometimes we don't know that we have these kinds of functionality on these machines, so our designs are restricted to the areas that we are familiar with. Even though we have the general concepts of the process, it would be better for our design if at least we have a general idea about the system. Even though you can ask people around, you should be able to know what sort of question you should ask.

DISTRIBUTED COGNITIONS

Increased acceptance of a constructivist view of human cognitions has provided support for the view that cognitions are better thought of as situated and distributed rather than decontextualized tools and products of mind. Accompanying this view is the proposition that social processes should be treated as cognitions (Resnick, 1991; Vygotsky, 1978). One of the reasons behind this recent interest in distributed cognition is the increasingly important role that activities with computer tools have come to play in handling intellectual tasks. In the view of Salomon (1991), it is observable that the collaboration of individuals and computers is often characterized by intellectually superior performance that cannot easily be accounted for by individuals' cognitions alone – a concept which Pea (1987; 1992; 1993) prefers to describe as “distributed intelligence”.

In this second part of this chapter we examine the data for evidence that students' metacognitive monitoring of their learning experience indicates the deliberate employment of distributed intelligence as a cognitive strategy.

DISTRIBUTION WITHIN THE GROUP

It has already been noted several times that one strategy employed by students with inadequate computing skills is to rely on their classmates to do the work on behalf of the group. However there is also strong evidence that all the groups consciously adopted a strategy of distributing the cognitive load in order to achieve their production goals.

LEUNG: At the beginning of the project we realized that the temple was quite complicated. We couldn't do everything at the same time. We wanted to minimize the complexity of the temple. We hoped that every member of our group could understand the details so we divided ourselves into two groups, one dealing with the roof structures and the other the column.... We had to contact the appropriate people and we had to get familiar with the software at the same time. We also needed to study the working drawings from the architects and try to understand what is going on in the drawings. Too many things. Working on a group basis, we can learn the pros and cons and also try to learn the good things from others.

The Morphing group also developed a working strategy which divided the cognitive load into two distinct domains: researching the historical development of roof construction; and knowledge of computer morphing techniques.

HOWARD: In my group we divided into different jobs. So that everyone may have their jobs but no one knows all of the procedures of the project. Some of them did the research and some of them did the final presentations. This means how to present animation in the computer. For example the ones that did the research may propose some kind of morphing story for

me, and we examine the feasibility of doing this and need to make some kind of compromise between us.

In other sections of this study the same argument has been put forward by all the groups: that there was insufficient time for everyone to do everything. Further evidence of this can be seen in the statements of Christina and Mo and from Joan (below) that this division of knowledge was also a source of some dissatisfaction.

JOAN: You have to (learn) something you don't know... otherwise you don't have the chance. Maybe if I did the 3D part I would have learned how to build a 3D model. But I am doing researching and everybody knows how to do it anyway. Just because Mo could handle it faster and easier, that was why we give the job to him. Maybe if we could have more time, we may have organized in a way that everybody doing a job they haven't done before.

Two distinct types of knowledge were distributed: computing procedural knowledge (i.e. how to produce particular effects using specific computer software); and domain knowledge, both declarative (e.g. the particular aspects of temple construction) and structural (i.e. the way in which the elements of a curtain wall construction interact as a system). The following sections examine evidence for these two propositions.

SHARING COMPUTER KNOWLEDGE

In the Maintenance and the Morphing groups, work was divided on the basis of computing skills. In Maintenance, Mo produced all the animation and became the expert on this aspect; in Morphing, Howard and Lun produced the morphing animations. In the Temple and Curtain Wall groups there was a deliberate effort to bring all the group members up to a reasonable standard of skill through peer teaching. In **Cognitive self-management**, p. 7:230, Wai explained how he refused from the beginning to be the "expert". In the quotation which follows, Christina describes how

the other three had to share their knowledge and skills in order to survive:

CHRISTINA: I think at the beginning WAI was the only one who actually knew how to use 3D Studio and the animation part. Then, he taught us and gave us a quick lesson. Then he was gone for two weeks for the Beijing project. Then three of us were in a panic. It was the first time we did the work without WAI, I think we did the work quite well. We made some mistakes but there were only a few people around that we could ask. Then we did this and we did that. If he was around, we could have done it in half of the time. That was the good way to learn because we actually made mistakes and we knew that. So, we went back and did it. That was good to learn it from each other. Couldn't miss out on that.

The Temple group used the same approach, with the more skilled operators taking on the most complex jobs at the beginning, but teaching the others as they went until everyone was able to function as an AutoCAD operator.

LEUNG: Not many classmates are that familiar with AutoCAD - I am one of them. We need to know how to operate it, therefore, we started a bit later than the rest of them who know it well. In a way, we shifted the work load to them at the beginning. They needed to do a bit more of the complicated part of the model, such as the curves. It was more easy for them to handle because they were more familiar with it. I am doing some parts without too many curvatures, as you see here - these mainly are walls, very straight forward. Since I am not very familiar with it, I don't need to spend a lot of time in it if I do this part.

SHARING DOMAIN KNOWLEDGE

The complexity of some projects meant that it was more practical to divide up the research into sub-sections and have individual members work on them, as in the Temple.

LEUNG: (William) came from Malaysia, he has spent a lot of time in studying traditional Chinese architecture. So, he is quite familiar with the background and history. At least his knowledge is better than ours. You know some of our students came from overseas and some of them are Hong Kong University graduates... The graduates of Hong Kong University are most skillful in using the computer software.

By contrast, the Curtain Wall group attempted to divide their work in a different fashion so that everyone would acquire the same domain knowledge but be responsible for different ways of presenting it within the hyperlinked Showcase presentation:

WAI: The members in our group are not allocated to a specific division, for example when you look at the Curtain Wall project you can see that it is divided into different precision projects, for example how to present working drawings and how to simulate the animation, so that the amount of work and the type of work is quite similar for different people. So that when I'm a member I have to do animation and do the Showcase... Everything at the same moment as the other members so that there is not a very... special for any one of the members in any field. We just share the experience and then do the work together. And we have the knowledge in nearly every aspect of the curtain wall project.

The result was, however, that while skills may have been exploited equally, domain knowledge was still distributed. Christina sees this as a drawback, and something which should have been addressed in the teaching strategy.

CHRISTINA: In our group I knew more on the fixed type of materials. WAI knew more about the overall structure of the curtain wall. He did the bigger animation and I think the roof, the parapet. Unfortunately I think we didn't have too much time to exchange knowledge about things other than what we showed in class or to each other. We didn't have a chance to ask like how did you come up with that openable window. It would have been better if we had been allowed a bit more time...

MAKING DISTRIBUTED COGNITION WORK

Making a decision to distribute the cognitive load within the group is one thing; making it work is another thing entirely. The Temple group, with eight members, found that it was as often as not a source of conflict which needed to be addressed through stronger leadership:

ALICE:. We are not coordinating very well because we have eight people in our group and we all have different opinions ,
(Actually) I would say that group work is the main problem.
Eight persons in the same group is trouble. We have all these different ideas which produce a lot of argument. I think if I will do it next time, we have to have better coordination. We have to cooperate better. I think if we assign a leader then the whole team will be work in a better way.

The Morphing group, with a clearer division of labour and a smaller number of participants had greater success in dividing the load:

HAN:. I think two of us working together would produce a better result because we can discuss together. If there are too many people, we might have different opinions. This is the reason why we work in team of two persons.

WAI-LING: Do you enjoy working in this way? In a team?

HAN: Its quite nice to work in a team.

“AFFORDANCES” OF THE COMPUTER SYSTEM

Pea (1992) poses the question: “How do tools serve as artifacts of distributed intelligence, carrying along with them new opportunities for contributing to activity, as defined by a community of users of such tools?” (p.51). In this section we examine the ways in which our “community of users” see the computer system as contributing to the kinds of activities *they* are attempting to carry through.

The qualities of the system which they describe fit neatly into what Gibson (1979; 1982) and Norman (1988) have termed “affordances”. The notion of “affordances” of objects which link perception and action is central to Gibson’s work on the psychology of perception. It refers to the perceived and actual properties that determine how a thing could possibly be used. Norman developed Gibson’s insights on affordances into what he called a “psychology of everyday things” in which he argued that better design of artifacts would make it easier to accomplish certain functions. (A relevant example in this study is the comments which students have made in this study on the awkwardness of the AutoCAD interface.)

There are many everyday examples of what Lave (1988) termed “smart tools” in which complex measuring activities are achieved through embodied “stashes” of numerical information: thermometers, speedometers, thermostats, etc. The computer tools which are used by the students in this study were primarily designed for the purpose of representing structural information, but they also provide examples of “affordances” which assist in the cognitive process, such as visualization, simulation and deconstruction.

VISUALIZATION

A basic skill for an architect is the ability to visualize a three-dimensional shape or space. For some people this comes more naturally than for others, as studies of field-dependence/independence have demonstrated

(Jonassen & Grabowski, 1993). One “affordance” of computer programs such as AutoCAD is the quality of translating 2D plans into 3D models; a quality of programs such as 3D Studio is the way in which they can be used to visualize complex shapes, textures, spatial relationships.

From 2D to 3D

Representing a solid object as a two-dimensional drawing is the fundamental task of an architect. Plans, elevations and sections of buildings are conventionally presented on paper in two-dimensions. Visualizing these 2D representations as three dimensional objects and spaces is also a necessary, but often difficult skill (e.g. the *dau-gung* model). If, however, the 2D drawings have been made using a CAD program, the computer can automatically produce a 3D model which can be examined, rotated and manipulated.

DESMOND: If we focus on 3D objects, hand-drawings can show one view only. It uses 2D images to imitate the 3D objects. Software like AutoCAD or 3D Studio can really build an 3D object for us... After I finalize my concept I can use the computer quite powerfully and successfully to visualize my ideas in terms of 3-dimensional format so that I can really experience what the space look like. It is very successful.

WAI: For example if you are a layman you look at a drawing and it says that is a “mullion”. You cannot get any image of it because it is just a two-dimensional section of the mullion, but for example when we project it into three dimensions you have an image of what it looks like in reality, and for the later stage we will assemble it using animation so that they can see what steps are (required) to assemble that thing. And then we look at the result and we think that it may convey the message.

YIN: (DISCUSSING THE *DAU-GUNG*) The drawings are all 2D. They just draw plan, elevation, that's all. But for a 3D model we need to consider each elevation and the plan at the same time,

so it is very different from this... I mean the computer can help us a lot in tackling these kind of 3D objects.

IAN: How can it help?

YIN: Because we can directly understand the jointing between the vertical plane and the horizontal plane, but in 2D drawing we can't - we just see the elevation, the other drawings of the plan. We can't understand at the same time.

IAN: But how does the computer help?

YIN: Because you can manipulate the object, so that we can three-dimensionally visualize the object.

IAN: How did people do it before computers?

YIN: They built it.

To assist understanding

The computer can be used to develop an idea at an early stage – to play around with forms and spaces and try out ideas. With the present state of technology one is restricted to crude shapes, to basic 3D building blocks, but this way of working is fast and very cost-effective. It is interesting that two of the three comments quoted below are from the follow-up interviews with Joan and Bonita, neither of whom were at all enthusiastic about computers during the BS1 course.

JOAN: If we use the computer in the early stage, we can draft out the block of the building and mainly see the "mass" of the building... Unfortunately, if you want to view it in a beautiful way, then it won't work though. I have tried to use the computer for my presentation before, say to draw some difficult shape such as an oval or some sort of object which needs to be replicated.

BONITA: I can treat it as a tool to visualize or to complete what is in my mind.... I mean the product may not be made with a computer but the result can be visualized in the computer. So, I prefer the (early) creative process to be done on the computer rather than hand drawings. So that the computer can create the drawings.

LEUNG: I think the computer is a very efficient laboratory. We can use the computer as a tool to do the experiment to test whether an idea is usable or not. Making a physical model might take one or two hours, but if you build up the model on the screen it might just take about five minutes and then you can do the testing on the screen to see whether you are satisfied with it or not.

All of the BS1 projects were designed for the lay public and most of the students believed that primary value of visualization was to explain a design or a system to a non-architect.

DESMOND: Through this project we are trying to present something that really is difficult to comprehend by people without any architectural knowledge. I think after the project I'll know how to demonstrate through the computer.

YIN: It is very important because only for those who have architectural knowledge, architectural training, who can read plan, section, elevation and relate them together. But for other people they can't. They find some difficulty to relate elevation, sections and plans. But if you've done a 3D model and... which can be more easy to help other people to understand.

In April 1995 two lecturers from the University of Eindhoven brought a demonstration of virtual reality to Hong Kong and the Department of Architecture was given funds under a research grant to develop a prototype VR engine. Students became aware that with very little extra effort the AutoCAD designs they had been producing could be turned into virtual reality environments.

MO: Actually, its a good tool for the demonstration of something which is more difficult to access to or to think of in reality. I think it actually can help us to visualize the actual space. For example, virtual reality - we can use it to help people to walk through the actual experience of the space. This kind of technology and price are beyond our reach at the

moment. So, I agree that at this stage the main role is the presentation rather than visualize for the other things.

LUN: Using VR ... you can walk into the space and interact with the elements. In the virtual space you can change the object shape and you can move it. So, there is more possibility for you to design using the virtual space.

Process

Once the students became aware of the possibilities of using 3D modelling for visualization, this itself became a performance objective. A great deal of the production process was devoted to developing techniques for effective visualization.

CHRISTINA: We are putting the texture and materials on top of it. Then we can link up the components to the major part of the building. Thus, we can improve the visualization. Another thing is how to reconstruct the system components on the computer and then present them realistically as computer generated images.

FAI: If we want to highlight any parts of it, it is supposed to show us the installation details of the selected part.

WAI-MAN: Because we usually have the image in our mind. We try to use the computer to build the exact 3D model for us to visualize something we can't imagine. To me, I can imagine the rough form or almost all the components and elements of the 3D models and then I use the computer to build it rather than use the computer to help me to imagine or to create another space.

LUN: Yes. How to control it to morph. But actually we know the development of the structural system is in that direction, but the problem is how we present it in computer graphics, so that it is more easy to visualize.

DECONSTRUCTION

ALICE: A benefit I can think of is it can show us the way how the components disassemble and assemble again.

Once a computer model has been constructed it can easily be deconstructed into its component parts. Students saw this quality as having two important cognitive functions: (a) aiding the architect to comprehend the system underlying a complex structure, and (b) clarifying the elements of a structure to the lay viewer.

FAI: Take this project as an example. I think I can really learn the way how to use it here. At least I can understand more details in building up the building and how to use the computer as well.

YIN: AutoCAD helps us in the understanding of the structure of the *dau-gung*. We can directly understand the jointing between the vertical plane and the horizontal plane, but in 2D drawing we can't - we just see the elevation, the other drawings of the plan. We can't understand at the same time. It will be much more difficult if we present it by hand drawings.

PRESENTATION

The two "standard" media for architecture students to present design work are: the 2D wall panel, incorporating plans, elevations, perspectives, photographs and textual information; and physical models. Computer modelling provides additional opportunities for the presentation of designs to clients and lay people.

LEUNG: It helps us in the presentation so that we can show others how the components are assembled in the system. As we've done in these SGI images. The quality of the visualization is much better than hand drawings and for the people who are not studying architecture, they would be able to understand the way the components are merged together and then form the building.

JOAN: To the client. It's actually helpful to visualize the building form or shape, especially for interior.

SIMULATION

The most powerful types of models are those which can be used for simulation. In BS1 the models were essentially representational, but the 11 students who went on to BS2 were involved in assisting two postgraduate students to develop simulation models for sunlight, ambient noise and aspect (views). This opened new and fascinating possibilities which both Christina and Han were considering employing in their final architectural thesis (a design exhibition).

CHRISTINA: (DESCRIBING WAYCAL'S SUNLIGHT SIMULATOR) Simply look at it and you can see how the lighting falls and where it falls and how bad it is. (Light affects) your emotion and psychological state of mind. So I see that side as very interesting, how we can use light and simulate an environment, and how people would react to it if you have a bright environment how people would think about that. So as a testing and simulation tool it is quite good I think.

For Han, the simulation model becomes a means of explaining to others a highly complex set of concepts which she had been working on for her thesis on a wildlife sanctuary information centre.

HAN: I studied the sun and I found journal articles on the subject. I read them and I understood them, but when I presented it to the others I think they needed the same time as I had spent (in order) to understand. So I think if the sun can be simulated in the computer it can be more easy for others to understand what I am trying to do. So the computer can simulate the sun, it can do the work (which) is more or less done by the articles, or by sections and angles which I have developed from the sun and seasons.

Howard's thesis presentation on migrant housing required him to find the most efficient utilization of a restricted and awkward space. Computer modelling enabled him to work from the inside out, placing

standard objects such as tables and chairs then constructing the simulated space around them.

HOWARD: A 3D model is part of the final presentation. I'll do some preliminary sketch, then I'd like to derive the size of the rooms from a small table, for example I lay out several tables in the rooms so that I can determine the optimum size of the rooms. If I use conventional tools, like pen and paper, it will cost me a lot of time to change and change and change again, but a computer is more convenient for me. So that I will use the computer in this way as my design tool.

STORAGE/MEMORY

Not surprisingly, information storage and retrieval (as in a data base) was an "affordance" which almost everyone was familiar with.

ALICE: I think the SGI system and AutoCAD are a good way for us to store and update the information, which is better than in the form of paper. Maybe especially for architecture.

JOAN: Once you collected all the information, the computer would be useful in preparing the materials for the final presentation or for the storage of them.

YIN: As a matter of fact, AutoCAD helps me quite a lot with drawings. It's good at producing some repetitive objects and the storage for the data as well. Also it's good for keeping records.

WAI: There are some things we need the computer to do it for us which we can't do with our brains. The best example is the memory. Apart the memory, I think it is rather difficult for us to see the computer as an extension of our body.

In March 1995 the computer lab set up a World Wide Web server separate from the official HKU server, which meant that students could produce their own home pages. The Internet became an issue and students

like Wai, Christina and Joan were quick to discover its potential as an information source.

WAI: We are now getting more exposure to CD-ROM or getting more exposure to Internet. I used to find information from books or magazines but sometimes if I do not have time, I'll search through the Net or use CD-ROM as a kind of media to learn or to get the information. So I think finding information through the computer is going to be important.

CALCULATION

The CAD program has no equal as a "smart tool" (Lave, 1988) in that the computer performs invisible, but incredibly complex calculations in the background in order to draw perspectives and perform rotations of 3D objects in "real time". Before CAD, architects and engineers needed to calculate every perspective separately – 30 years ago they used a slide rule, more recently it required complex mathematical modelling.

DESMOND: We need to calculate the exact locations of the model structure and then specify the shape and the size of it. The final product has to be some degrees quite accurate, reasonable, and logical, but architects and architecture students do not like doing calculations.

MAN: The Temple group obtained a lot of help from the computer. Without the computer, you need to create the model by yourselves and the size of the model might not be exact. The 3D models generated from the computer will be very accurate. It can cut down a lot of steps in the design process.

DOCUMENTATION

Documentation is integral to assessment in Architecture. Students must hand in working drawings and research notes together with the final presentation so that the lecturer can see the process by which they arrived at the result. Bonita sees interim computer models as a useful part of that documentation.

BONITA: I used to only apply it (computer models) in the design stage of my course work so that I can present it to my lecturers. Now, I also assign it to my documentation in order to show them what have we learnt here. It could be some sort of design that you have made in the entire project.

PROJECT MANAGEMENT

As their computer skills improved, students discovered that they could use the system to do more than simply use application programs. They could write small programs to automate operations such as merging files, synchronizing sound and image, conducting repetitive operations and checking on progress.

FAI: It helps us to control the coordination of different parts of our project. Such as Showcase, it can coordinate the sound and pictures for us.

WAI: I think another kind of computer help is the management. If you have so much information, computer can help you to manage the data, even joining (merging) the data. It helps you to convert data into different files, different forms. I think the management part is as essential to me as the physical tools. I think in the future, it will take more part in the management role.

“A COMMON LANGUAGE”

An interesting insight from Wai was the way in which using the “common language” of computer modelling can assist distributed production by concealing the individual styles of different designers in order to present a coherent “look” to the project.

WAI: In the group the computer can be a common language. For example, when we join a drawing, you will not be able to distinguish the drawings of different people. You can spread the jobs to different people (but the whole job will have) the same appearance. Then, the productivity will be high.

INTERACTIVITY' (A NEW FORM OF PRESENTATION)

Interactive multimedia offers possibilities for presentation which have not existed previously.

MO: You see this is kind of interactive functionality, so you can do anything you like here. For example, you can put them side by side and see the relationship between them. In the old days, you might only be able to read the description through the text., which is much less interesting than this. I think you can understand more through this way.

Through software such as Showcase and Internet resources, knowledge could be perceived as "distributed" on a world-wide basis. Christina and Lun had been involved in the "Virtual Design Studio" project in which students at five universities (Hong Kong, Barcelona, Warsaw, MIT, Vancouver) had all worked on the same project and communicated through the Internet.

CHRISTINA: Using computer is very flexible now, in terms of different software you can use to present. For example, HTML is very popular. It's easy to present information to other people and easy to change and update it quickly and it doesn't take too long to learn how to use it. Once you make your home page, you can put it on the Net and then everybody can see it around the world. It's not at all like the formats we use now where you present your work on the wall or paper. You can send it to anywhere and everybody with access to the Internet or computer can see what you have done.

LUN: Computer can allow (enable) people to experience architecture - like the Internet. The computer can be a medium which provides a lot of knowledge about architecture. I believe the computer can give opportunities to other architects - it's another channel for them to study the structure.

COMMUNICATION

As the term progressed, more students became aware of the possibilities of the computer system as a medium of communication. In addition to the World Wide Web, there was e-mail, telnet, ftp or simply leaving a message on the server for a classmate to read the next time they came in.

JOAN: It is important to present the ideas (and) to be able to communicate with other. If you have an idea and that cannot be read through by other, then it's useless. If you can find whatever media, like computer, model or drawings, anything ... In architectural presentation drawings and models are more important than verbal (information). Computer is a good medium for displaying these.

RONALD: I think the important thing is that it can have an E-mail function. People can write letters or notes to other members of the group through the computer. I learned that I can use the computer as a communication tool within the group. But at the time of the project we had not fully utilized this program. After finishing Building Systems I, I install the WWW in my PC and I always use the E-mail.

You didn't need to be "Computer Man" to be aware of these new possibilities – everyone was talking about them. Frankie might not have been sure which application program was appropriate for communication, but he was keen to keep up with the trend.

FRANKIE: I like to learn (new) software because it's the way you will be communicating with others in the future. Let's say, my classmate writes to me in Powerpoint – if I don't have Powerpoint, I won't know how to look at his work. You can be related to the world. It's a must.

CONCLUSIONS

This and the previous chapter have both described in different ways the interaction of student characteristics, computers and cognition – in other

words, the process of cognitive construction. While Chapter 6 described the process from an external, third-person perspective, Chapter 7 has attempted to view the interactions from the point of view of the participants. These were articulate and experienced learners who had developed approaches to learning which had served them well for the past four years. However these approaches did not always work in the face of the considerable creative, computing and interpersonal demands of the BS1 course: they needed to develop new strategies for learning and for distributing the cognitive load. Some students were better at it than others. This is one issue we take up in the final chapter.

Chapter 8

Outcomes

Summary: The final chapter draws together the themes which have emerged from the investigation of the research question. The naturalistic structure to the research is presented as an advantage, having furnished the opportunity for unexpected outcomes (both process and product) to emerge from the data. The study provided support for constructivist theories of learning in tertiary education; and for the use of computers as cognitive tools in professional education. It also produced a number of innovative methods of profiling students. A hypothesis is suggested concerning the requirements for success in this type of learning environment and is tested against the data. Finally, we consider the long term effects of the approach to professional education which has been examined in this thesis.

RESTATING THE RESEARCH QUESTION

The basis of this research project was not a hypothesis, but an open-ended question:

In a problem-based, computer-intensive learning environment, what is the nature of the interaction between student characteristics, computers and cognition?

Addressing the question involved collecting, indexing and searching a great deal of data over 18 months in order to produce what Guba and Lincoln (1982; 1988) see as the ultimate goal of qualitative research: “perceptions, insights and coherence”. The question could be represented graphically by the Venn diagram in

Figure 8-1, where the learning environment is the enclosing square and – were this a typical educational technology study of the 1970s of the style described by Clark (1983; 1994) – the three “variables” might be represented by the circles.

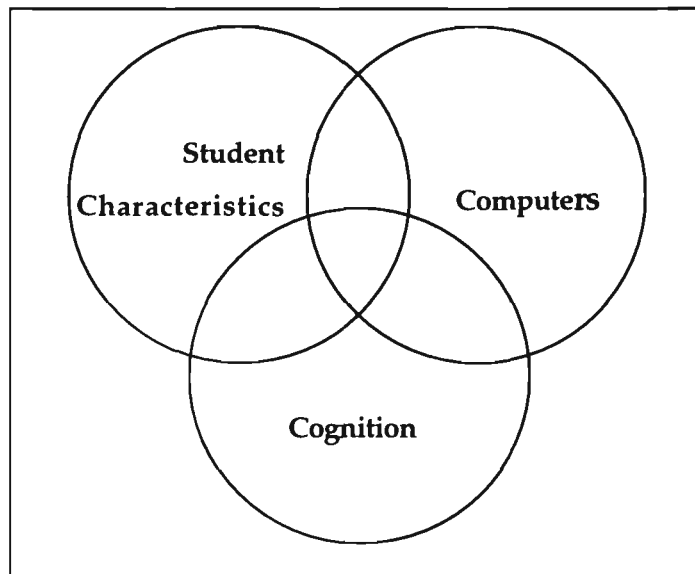


Figure 8-1: The research question

The first thing to note is that there is not just one “interaction”: there are at least four. The second thing to note is that each of the so-called variables is a multifaceted concept, so there is also the possibility of interactions *within* each of the circles. e.g.:

- **Student characteristics** comprises the SPQ scores (6 scales), computing knowledge (3 scales) and two models of structural knowledge, as well as the observations of the teaching staff and the researchers;
- **Computers** encompasses the laboratory and its hardware, the network and server and the range of available software;
- **Cognition** includes subdivisions of domain and computer knowledge, cognitive constructions (i.e. the process and outcomes of the projects), metacognitive knowledge and distributed cognitions.

This complexity provides strong reinforcement for the arguments of Biggs (1995), Reeves (1990) and others quoted in Chapter 1, that in education, single variable, laboratory studies are of little value in reflecting the convoluted interactions of the "soft, slimy swamp" (Schon, 1987) or "the process of a tornado" (Kozma, 1994) that we call education.

Nevertheless, while it may not be feasible to demonstrate the effect of a single variable on the quality of student cognition, it may be possible to offer some conclusions about the process and outcomes of the study, which have a degree of external validity as well as a level of generalizability.

PROJECT OUTCOMES

The outcomes of this research project lie as much in the process as the product. In fact the two are inextricably intertwined and the credibility of the conclusions can only be judged in light of the processes which were employed to distill them from the data. In Chapter 1 we quoted Richards:

The test of the ultimate conclusion is ... to see how elegantly and methodically the evidence was shaped into the conclusion, how the conclusion was coaxed ... to "emerge" from the data, how evidence and grand account form a well-connected, seamless web of belief that illuminates and enriches our perceptions and understanding of phenomena we see every day. To be credible, the report must show these processes in action, and demonstrate how the conclusions were reached. (Richards and Richards, 1992)

The fundamental aim of this project, therefore, has been to demonstrate, through the methodology of data-driven research, the process of cognitive construction using computers as the primary cognitive tools.

What conclusions can we draw from the outcomes of this process?

I. RESEARCH PARADIGMS

The project has demonstrated the value of qualitative, data-driven research methods for studying rich and complex learning environments. By choosing not to operate with the restriction of a hypothesis which defined the type of data to be collected, we were free to accumulate whatever information was available and appeared to be relevant at the time (interviews, storyboards, videotapes, screen captures, mental models, timetables, etc.). This pool of heterogeneous and unstructured data was then refined and organized through the use of established qualitative research methodology such as grounded theory (Strauss and Corbin, 1990), data reduction (Miles and Huberman, 1988; Miles and Huberman, 1994) and theory-building (Richards, 1993; Richards and Richards, 1992) in order to produce results which could be tested both internally for consistency and externally through triangulation with other results.

This approach resulted in some unexpected outcomes which we hope to pursue further in future research, e.g.

- The picture-in-picture (*p-in-p*) video system, developed for this project to observe the progress of students working on computers, is of obvious value for research in the wider field of human-computer interface design. A research proposal based on this technique has recently been submitted to the University Research Grants Committee.
- The use of PFnets to elicit descriptions of structural knowledge shows great promise and after further investigation using a larger sample, will be written up separately as a journal article.
- NUD•IST, originally designed as an instrument for qualitative research in the social sciences, has proved to be an invaluable cognitive tool for the structuring of data about learning. Further longitudinal studies of innovative practice are being planned for the Faculties of Medicine and Engineering. The refinement of this tool for educational

research will be pursued through Internet discussion lists such as *QSR-Forum* and *IT-Forum*.

II. PARADIGMS OF LEARNING

The study has reinforced the relevance of qualitative paradigms of learning in university level professional education: constructivism, PBL, structural knowledge, etc. The *Pedagogy* section of *Chapter 7* confirmed that the most metacognitively aware students preferred to see learning as a constructivist (as distinct from instructivist) process and that the construction of new knowledge involved “acquiring new administrative ways to use what one already knows” (Minsky, 1986).

The constructivist-instructivist dichotomy was demonstrated clearly by the ways in which students reacted to the two halves of the BS1 course. The first term comprised a series of lectures, assessed by examination, wherein students were required to be passive learners and to rely on memory. In the words of Christina:

...In Hong Kong if you can memorize it well then you do OK.
This is what I don't really agree with. In terms of learning...
They shouldn't just require you to have a good memory. It
doesn't mean anything after the exams if you can memorize it
and then forget everything.

It could be inferred from this that a causative factor behind some of the surprisingly high surface strategy (SS) scores on the Study Process Questionnaire from metacognitively aware students such as Christina, Han, Howard, Leung and Shirley, was the reliance on examination to assess the first semester of the Building Systems course (the SPQ questionnaire was administered just three weeks after the examination). As we noted in *Chapter 4* the result provides reinforcement for Biggs' (1992) view that “(while) academically speaking a surface approach cannot be satisfactory; existentially speaking (it) may be a sensible way of handling a difficult situation” (p.10).

In the second half of the year students were offered the opportunity to design their own learning, the outcomes of which were described at length in *Chapter 6: Learners as designers*. The four case studies are descriptions of how the students literally constructed “new knowledge” in the form of interactive presentations directed at explaining complex structures and concepts to a third party. The exercise involved them in researching and developing their own insights into domain areas (structures, history, components, design) and computing (software, working methods, production techniques). It also involved them in developing new ways of working which included distributing the cognitive load between colleagues and with the computing environment, described in *Chapter 7: Cognitions*.

III. COMPUTERS AS COGNITIVE TOOLS

The Action Research Project provided the opportunity to study the efficacy of computers as cognitive tools in architecture education. The assumptions underlying this approach to teaching professional courses were corroborated by the study. The students in the BS1 course acquired a range of new skills and developed innovative ways of approaching the tasks of designing structures, testing their ideas and communicating with peers and clients. In addition they came to appreciate the “affordances” offered by computers for their project work and ultimately for their futures in the architecture profession.

While many of them found the course of study difficult and the learning environment frustrating, in retrospect (12 months later) most expressed positive opinions about the experience. Much of their frustration was caused by the crowded curriculum and the competing demands of the timetable. The Architecture faculty has recognized this and is currently restructuring the curriculum so that it can better accommodate problem-based courses; and has made a considerable

investment in enlarging and equipping the computer laboratory so that more students can take advantage of working in this environment.

IV. DEFINING STUDENT CHARACTERISTICS

In the course of this project we employed a battery of student profiling tools to supplement the naturalistic data from sources such as open-ended interviews and observations. This profiling technique provided a great deal more information than, for example, tests of intelligence or aptitude, and could equally be employed outside the research context to diagnose students' conceptual and study difficulties.

STUDY PROCESS QUESTIONNAIRE

Biggs (1992) originally developed the Study Process Questionnaire as a diagnostic tool to clarify the reasons why students might not be performing to expectations, e.g. high scores on *surface approach* indicate a student who may not see the value of expending cognitive effort on understanding when he believes that the assessment will only require short-term memorization of facts. In Biggs' view, the ideal learner is characterized by a *deep-achieving* approach, which combines:

... wide reading, discussion with teachers and other students, playing with the task, thinking about it constantly... (and) being self-disciplined, neat and systematic; planning ahead; allocating time to tasks in proportion to their importance, keeping clear notes, and all those other planning and organizational activities referred to as "study skills" (pp. 11-12)

While the averaged SPQ scores from the BS1 class correlated closely with Biggs' normed cluster for senior university students, within the class there was a great deal of individual variation. As noted above in III. PARADIGMS OF LEARNING, there were some initially surprisingly high scores on *surface approach*; but there were also some extremely high scores (top 10%) on *deep motive* and *strategy*. The SPQ profiles of the most successful students

in the BS1 class provided high scores on *deep motive* and average to high scores on *deep strategy*, but not necessarily average or high scores on either of the *achieving* scales.

COMPUTING KNOWLEDGE

In the late 1990s, a basic knowledge of computing has become a prerequisite for study in virtually every profession. In computationally intensive professions such as engineering and architecture, computer software packages such as AutoCAD have redefined work practices as well as the means of storing and transferring information. For students in these disciplines, knowledge of specialized software packages has become as important today as was mastery of the slide rule or logarithmic tables 20 years ago.

This study examined students' knowledge of the range of computer applications which are useful for the production of 3D computer models and characterized the necessary knowledge and skills under three headings:

- declarative knowledge (knowing *that*) describes what the student knows about the interface and the functions of the various tools for producing a desired output (25% of the interviews contained references to computer software);
- procedural knowledge (knowing *how*) describes the skill with which a student uses the computer tools to produce the desired result;
- contextual knowledge (knowing *where, when* and *why*) describes the student's knowledge of the criteria necessary to select appropriate software and hardware to achieve a desired result.

The computing knowledge scores developed in the course of this study demonstrate, when compared with other measures and course results, that declarative and procedural knowledge may not be as

significant as contextual knowledge in predicting success. On the whole, students do not (at least yet) regard practical computing skills as essential for success in architecture and many find it difficult to reconcile a computer's prescriptive interface with the flexibility required for creative design. On the other hand they value the computer's accuracy and speed and the "affordances" it provides in calculating perspectives, replicating complex shapes and facilitating experiment and simulation.

STRUCTURAL KNOWLEDGE

Jonassen, Beissner and Yacci (1993) regard structural knowledge as the essential link between declarative and procedural knowledge. In this study structural knowledge emerged as the central element in a student's ability to reconcile the sometimes conflicting demands of creative design in a computer-intensive environment. Students with clearly developed structural knowledge were better able to function in the BS1 environment: to apportion their time, to use productive strategies and to work in groups; in fact the students with the most highly-developed structural knowledge tended to be the group leaders.

A number of methods were employed to elicit and describe structural knowledge (these are collected in *Appendix 1*):

- Buzan mind maps were used at the beginning of the study to develop graphic representations of computing knowledge;
- As a means of diagnosing the problems which the groups were having with lost files, all students were asked to draw their "mental model" of the laboratory's network and server. The results provided phenomenographic evidence of the conceptual difficulties which many of the students were experiencing;
- Pathfinder networks, described by Schvaneveldt (1990) and produced using the KNOT software, provided illuminating insights into the level

and connectedness of structural knowledge of individual students. The four characteristic PFnet patterns correlated closely with other characteristics such as deep approach to learning, contextual knowledge of computing, structural knowledge of the network and metacognitive awareness.

Taken together these indicators provided valuable insights into the underlying basis of student performance.

V. METACOGNITIVE AWARENESS

Awareness of the processes of learning and knowing emerged as a central ingredient of success in this collaborative, computer-intensive learning environment and the metacognitive issues which emerged from the data were described at length in *Chapter 7*. They include attitudinal factors such as enjoyment or dislike of computing, PBL and collaborative learning, as well as self-knowledge and task knowledge: the type of factors Flavell (1979) described as “metacognitive knowledge and experiences”; as well as “goals and actions” comprising such strategies as the conscious use of distributed cognitions to achieve performance objectives.

There was no attempt to develop a measure of metacognitive awareness on which to rate students. A crude procedure such as comparing the number of text units contributed by each student would be meaningless since some students, like Alice, Joan, Wai and Bonita, had comparatively little to say (in terms of text units), but all four contributed perceptive and significant insights. The types of insights also varied according to the experience and backgrounds of the students: Christina, Joan and Leung provided overseas perspectives; Howard, Mo and Wai were highly proficient with CAD and animation software; Alice and Frankie were exceptionally skilled paper and pencil designers; Han and Christina were very effective project managers.

The quotations in Chapter 7 would appear to provide a subjective impression of which students exhibited the highest overall metacognitive awareness: the contributions of Christina, Han, Howard and Leung in particular stand out on volume and variety of contributions alone. However the quotations in this chapter were chosen on the basis of representativeness and, in fact, almost all students expressed the same opinions in some form or another. There was an effort to represent as many students as possible, but the basis for choosing between alternative passages was normally made on the criterion of effective communication, so the most articulate students end up being better represented.

From the evidence of Chapter 7 it is logical to conclude that a high degree of metacognitive awareness is essential for success in this type of learning environment, involving as it does the need to work both independently and collaboratively, to learn new and complex skills, to manage time, and to communicate effectively.

HYPOTHESIS

On the basis of the evidence from this study it is feasible to develop an hypothesis about the requirements for successful learning in this type of environment:

In a problem-based, computer-intensive learning environment, the most successful learners will exhibit a deep approach to learning, a high degree of contextual knowledge of computing, well-developed structural integration of domain and computing concepts, and metacognitive awareness

WHAT IS “SUCCESS”?

Defining “successful learning” is something we have not attempted so far in this study. To a constructivist, all learning is successful to a greater or lesser degree as it involves the achievement of personal goals. However in

formal university-level study, assessment (results) is what determines success, at least in the short term, and students will tailor their approach to learning in order to meet the criteria of assessment.

ASSESSMENT CRITERIA

As we noted in II. PARADIGMS OF LEARNING, p.8:259, if assessment is based purely on recall of facts as tested by written examination, students will adopt a surface approach, concentrate on declarative knowledge and give emphasis to memory. If, on the other hand, assessment is based on problem-solving and creative performance, a deep approach will be rewarded and students will need to put more emphasis on the development of procedural skills and contextual knowledge. It follows, therefore, that if success is to be defined in terms of assessment, then the marks awarded must be based on problem solving, deep approach characteristics such as wide reading and involvement with the topic, and procedural and contextual knowledge.

1. Problem solving:

The focus of the course involved "solving" a problem concerning the presentation of complex architectural information. Assessment was not so much concerned with the "solution", i.e. the quality of the final presentation (which would in any case have been problematic in the light of the computer crash); but the processes the students went through on the way to producing the final product.

2. Deep approach

According to Marton (1986) and Biggs (1992) students taking a deep approach will be prepared to search for analogies, expand the topic to follow side issues and theorize about what is learned. Deep learners will:

- aim to possess a great deal of relevant content knowledge,
- operate at a high or abstract level of conceptualization, and
- use optimal strategies for handling the task.

3. Procedural & contextual knowledge

“Solving the problem” required the mastery of 3D modelling and computer presentation techniques in a highly-sophisticated computing environment. In theory, a student who began the course with low computing skills but developed throughout the term could score as high a mark as a student who began with high level skills. In practice, however, there was insufficient time for novice computer users to develop skills in unfamiliar software and it was left to skilled users like Mo, Howard, Wai and Desmond to master lighting, rendering, hyperlinking and animation. But students discovered that in working in a collaborative environment, it was not always necessary for everyone to be able to perform equally: contextual knowledge – the ability to envisage ways in which different software can be employed to accomplish a task – was an equally important skill. And as we have noted above, even more important was structural knowledge – the ability to make connections between computing and domain concepts, and between procedures and outcomes. Students with these abilities, like Christina, Han and Yin, were just as valuable to the group as the virtuoso computer modellers.

4. Collaborative

A team approach to production was a central objective of the course. Students were required to contribute to the work of the group, which involved peer teaching as well as collaborative learning.

Credit was awarded according to the contribution which individuals made to the success of their group projects.

ASSESSING BS1

A great deal has been written on ways of assessing collaborative learning in computer environments: see for example, Carver, Lehrer, Connell, and Eriksen (1992), Goldsmith and Davenport (1990), Reeves and Okey (1996) Rockman (1992), but this literature has not penetrated very far into the practices of assessment in university Architecture courses. Although the approach to teaching the BS1 course may have been innovative, Barry Will's methods of assessment closely followed the traditional "studio" approach which relies on close and constant monitoring of student work by one or more "critics": see for example Dinham (1988; 1989). To employ Reeves and Oakey's (1996) terms, studio assessment is a combination of *Authentic Assessment*, in which both the task and the assessment are highly situated; *Performance Assessment*, in which learners "demonstrate their capabilities directly, by creating some product"; and *Portfolio Assessment*, which takes account of process as well as product. (pp.192-194)

BARRY: Because it's group work ... the only way I could do it is to look at their files. To look at the time they've spent on it. And then to sit down with each one of them in each group and try to identify how much they actually understand of the thing and how much they don't. I also use the teaching assistants to help me judge this. So it requires a fair knowledge and a fairly close knowledge of what the students are up to.

The validity of studio assessment relies heavily on the expertise of the assessor: Barry Will has over 20 years experience as a university teacher and considerably longer as an architect; he has worked in three universities, served as Head of School and has been Dean of the University of Hong Kong's Faculty of Architecture for the past five years. He does not rely solely on his own observations, but solicits the opinions

of laboratory staff and supervisors and discusses assessment criteria with the students themselves at several points throughout the semester.

It is important to emphasize that the data from this research project was not available to the teaching staff at the time and played no part in the assessment process.

In practice, assessment began on Day 1 when Barry Will allocated students to groups so as to ensure that computing expertise was evenly distributed. Peer teaching of computer skills was a stated course objective.

BARRY: I believe, after having taught these areas for a long time is, I can teach some of the students quite quickly. They already know a lot - some of them have been using computers for years. What I expect is for them to then teach the slower students.

Each Friday the groups presented and discussed the current state of their project work following the model of the "desk crit", and during the week they worked under the supervision of teaching assistants (Ph.D. students) and the laboratory technician. Consequently, assessment was heavily weighted towards creative involvement in the project and communication skills.

BARRY: I have pretty good idea at the beginning of the project of how capable they are. By the end of the project what I will be doing is asking the weaker students to actually run the systems for me and to show me they understand it, so even though they may not have necessarily done the basic inputting, I would check that they would have a comprehensive knowledge of it. To do that they will probably end up doing more work than the person who put the 75% of (the computing) work in. Because they will have had to have learned the program and have understood it.

Our observations showed that this was not necessarily the case in the 1995 BS1 course. As noted on p.8:267, most of the weaker computer

users did not learn new programs or skills, they simply refined the AutoCAD skills they already possessed. The problem was lack of time, and this issue has been addressed in subsequent courses.

The final form of the assessment was the letter grades in Table 8-1: Student profiles. For the purpose of this exercise, these have been arranged in an unofficial rank order based on Barry Will’s notes. Grades from A to D represent pass marks – nobody failed the unit.

TESTING THE HYPOTHESIS

To test the hypothesis we can now compare the ranked scores on BS1 with the measures of student characteristics described in Chapter 4 and on p.8:261 to see whether there is any relationship between success in the course and factors such as deep and achieving approaches, computing knowledge and structural knowledge.

NAME (Ranked)	SPQ						COMPUTER			PF-NET Shape	MENTAL MODEL
	SM	SS	DM	DS	AM	AS	Dec	Pro	Ctx		
SCORE: A											
Wai	-	0	+	+	0	0	H	H	H	Branching (2)	5:H/r
Han	0	0	+	0	0	+	L	A	H	Branching (2)	5:H/r
Christina	0	+	+	0	-	-	L	A	A	Branching (2)	4:H/bs
Yin	-	0	+	0	0	+	H	H	H	Branching (2)	4:H/bs
SCORE: B											
Howard	+	+	0	0	0	-	H	H	H	Web (2)	5:H/r
Desmond	-	-	-	0	-	-	H	H	H	Web (2)	4:E/bs
Mo	0	0	-	-	-	0	H	H	H	Web (2)	3:H/bs
Leung	0	+	+	+	+	+	A	A	H	Web (3)	3:H/r
SCORE: C											
Alice	0	-	-	-	-	-	L	A	L	Cats Cradle	3:H/bs
Yatman	-	-	0	0	-	-	A	A	A	Branching (2)	2:FR
Frankie	-	-	0	0	-	0	A	A	A	Web (1)	2:R
Bonita	0	-	-	-	-	0	A	L	L	Branching (2)	4:H/bs
Joan	-	-	+	+	-	0	L	L	L	Cats Cradle	1:F
Waiman	-	-	-	-	-	-	H	A	L	Linear (2)	1:F
Fai	-	0	0	0	0	0	L	L	L	Web (2)	3:E/bs
Shirley	0	+	0	+	0	+	A	A	A	N/A	3:H/bs
SCORE: D											
Ronald	0	-	0	+	-	0	L	A	L	Linear (3)	3:H/bs
William	0	-	+	+	+	0	L	L	L	N/A	N/A

Table 8-1: Student profiles, ranked by BS1 assessment

Table 8-1 is a matrix which summarizes the Student Profiles. It sets out ranked assessment in BS1 (Column 1) against four profile indicators.

1. The **Study Process Questionnaire** scores are reported using the shorthand format employed by Biggs (1992):
'-' atypically low; '0' average; '+' atypically high
 Therefore a score of: **- 0 | + + | 0 0** indicates a very low score on surface motive (SM), average on surface strategy (SS), atypically high scores on deep motive (DM) and strategy (DS), and average scores on achieving motive (AM) and strategy (AS).
2. The **Computing Knowledge** scores relate to Declarative Knowledge (Dec); Procedural Knowledge (Pro); and Contextual Knowledge (Ctx) which are either High (H), Average (A) or Low (L).
3. The **PFnet** shapes: *Cat's Cradle*, *Web*, *Branching*, and *Linear* are followed (in brackets) by the number of foci or nodes.
4. The code for the **Mental Models** is in three parts:
 - the first number is the 'Accuracy' score (5 is comprehensive and accurate, 1 is totally inaccurate);
 - the Letter code defines the model style: Hierarchical (H), Explanatory (E), Representational (R), Fanciful (F);
 - the letter following the slash indicates the depth of the hierarchy (if applicable): Root down (/r) or merely the Building Systems sub-directory (/bs).

Therefore the code **5:H/r** refers to an accurate Hierarchical shape originating at the Root and the code **1:F** refers to a totally inaccurate and fanciful representation.

The matrix makes it apparent that there are a number of relationships between the student profile scales which provide support for

the hypothesis: these are indicated by the highlighted (grey-background) cells in Table 8-1.

RELATIONSHIPS

1. **The “A” students** all took leadership roles within their groups, both in conceptual and management terms. According to Barry Will: “they stamped their personalities on the projects.” They all displayed:
 - above-average SPQ scores on deep motive (DM) and average or higher on deep strategy (DS), which indicates an overall **deep** approach to learning
 - high (or high average) **contextual** knowledge of computing, though not necessarily high on declarative or procedural
 - a **branching** PFnet pattern
 - their Mental Models were **hierarchical** and scored 5 or 4 on accuracy.
2. Three of the **“B” students** were the main contributors to the computing activities and the fourth, Leung, designed the storyboard and did most of the historical research for the Temple project. Without their expertise it is likely the projects would not have been completed at all. They all displayed:
 - highly-developed declarative, procedural and **contextual** computer skills (in Leung’s case, a high level of contextual knowledge only)
 - a **web** PFnet pattern
 - their Mental Models were **hierarchical** (Desmond’s was Explanatory, but displays an awareness of hierarchy) and scored at least 3 for accuracy

3. There appears to be no commonality among the “C” and “D” students in the SPQ, computer knowledge or structural knowledge scales.

OBSERVATIONS

Barry Will's statements about his assessment methods (p.8:268) indicate that marks were awarded according to the student's contribution to the project and his/her understanding of the computing processes involved. Leadership and peer teaching were also heavily weighted.

All students passed the unit and were, therefore, “successful” in conventional terms, and as we noted in V. METACOGNITIVE AWARENESS (p.8:264) all students displayed a level of metacognitive knowledge. However, the data from this projects indicates that there were four “particular characteristics” from the student profile which appeared to be ingredients for higher levels of success (A and B scores) in a problem-based, collaborative, computer-intensive learning environment.

Criteria for achievement

1. Strong intrinsic motivation, indicated by an above average score on deep motive (DM);
2. A high level of contextual computing knowledge;
3. Well-developed structural knowledge – indicated by a branching or web PFnet pattern (branching is better); and
4. An accurate and hierarchical Mental Model of the server.

“A” students

Wai, Han, Christina and Yin met all four criteria. They assumed group leadership roles, they had high intrinsic motivation (deep motive scores) and, Christina's SPQ score notwithstanding, could all be described as deep-achievers; they all displayed a clear understanding of the role of computers in the design process (contextual knowledge); and they exhibited highly

developed structural knowledge (as evidenced by the PFnets and Mental Models).

"B" students

Howard, Desmond, Mo and Leung met three of the criteria and made major contributions to the computing and conceptual content of the projects. They displayed a mixture of intrinsic and extrinsic motivation (as evidenced by their surface and deep approach scores), as well as a range of computing skills, but all displayed a high level of contextual knowledge. Their PFnets were also well-structured, but indicated a focus on just one or two issues.

CONCLUSION

There is, therefore strong support for the hypothesis. The highest achieving students exhibited an overall deep approach to learning (with above average scores on deep motive) and a high level of contextual computing knowledge and structural integration of domain and computing concepts. The next highest achieving students (B) also displayed a high level of contextual knowledge, but had lower scores on deep approach and tended to focus domain and computing concepts around one dominant idea.

There is not, however, sufficient evidence to prove the corollary: a deep or deep-achieving approach does not of itself predict high marks (Cf. William and Joan); nor does a structured learning schema, as evidenced by a branching or web PFnet (Cf. Yat-man, Frankie and Fai) .

A high level of contextual computing knowledge was the most common factor in the achievement of high grades.

FOLLOW-UP: 12 MONTHS LATER

EFFECTS OF INTELLIGENT TECHNOLOGY

In Chapter 1 we briefly discussed the distinction posed by Salomon, Perkins and Globerson (1991) and Salomon (1993) between effects *with* and effects *of* computer tools: "... working *with* an intelligent tool has effects on what students do, how well they do it, and when it is done", whereas effects *of* the technology refers to perceived "changes in mastery of knowledge, skill or depth of understanding once the student is away from the computer." (Salomon, 1993, p.3)

The focus of this thesis has been on the first paradigm: effects *with* computer tools. We have observed how the computing environment redefined the task of conceptualizing, drawing and presenting information and have noted the particular student characteristics and levels of cognition which are prerequisites for success in this environment. The effects *of* computers is more problematic. Salomon questions whether it can be demonstrated that working with intelligent tools leaves a "cognitive residue" in the form of improved ability to conceptualize a form or a space, or to communicate this information in their absence?

This is not an easy concept to quantify, and demonstrating it would require a much more detailed and longer-term study than this. But follow-up interviews and observations 12 months later provided some indications of longer-term positive effects of the experience of working with computers as cognitive tools:

1. Students who were sufficiently engaged by this style of learning environment to enroll in the Building Systems 2 option the following year.

Christina, Han, Howard, Joan, Leung, Lun, Mo, Ronald, Wai, William, Yin.

2. Students who saw value in improving their computing skills by working to complete the Temple project over the Summer vacation¹; *Christina, Han, Howard, Joan, Lun, Yin.*
3. Students who reported in the final interview that completing the BS1 course had changed their view of the design and presentation process and/or 3D computer modelling had been used in their Design Thesis. *Christina, Desmond, Han, Joan, Howard, Leung, Mo, Ronald, Wai, Yin.*

EFFECTS OF THE BS1 COURSE

Building Systems 1 was one of 16 elective courses (8 to be chosen) on offer in the two-year M.Arch. course. Electives make up only 40% of the assessment, so the result contributes only about 5% to a student's final mark. Most of the students agreed that it was the most productive of the electives in their course and had the most profound influence on how they approached the Design Thesis in 5th year (the Thesis is collaborative in that each student has six undergraduate assistants).

This study has provided evidence of significant cognitive gains resulting from the problem-centred approach to professional education combined with access to powerful cognitive tools. Whereas instructivist style, lecture-examination methods appeared to be neither rewarding to students nor particularly effective; the situated nature of the BS1 curriculum, its collaborative, problem-based methodology, and the presence of sophisticated computer tools encouraged intrinsic motivation and deep approaches to learning through which students were empowered to construct their own knowledge and meaning.

As a result of this study, plus the impressive output of the latest cohort of BS1 students, the University of Hong Kong's Department of

¹ Wai was unable to participate as he had to return to Beijing to collect first prize in an international computer design competition.

Architecture and Teaching Quality Committee have recognized and accepted the significance of this approach through the granting of Teaching Quality Improvement and Research funding. There is currently a debate at Faculty level about how the Architecture curriculum can be altered to accommodate more PBL courses, increase access to computing facilities and provide valid assessments of collaborative student work. In recognition of the problems experienced by the 1994 cohort of students (time, organization, lack of computing skill, etc.) the Building Systems course has been expanded into BS1 and BS2.

As mentioned in I. RESEARCH PARADIGMS p.8:258, further Action Research projects are planned into the use of PBL and computers, both as media of content and instruction and as cognitive tools, in the Faculties of Medicine and Engineering. We anticipate that the insights gained from research into innovative practice, as exemplified by the Building Systems experience, will provide a "trickle-down" effect on curriculum construction and teaching methods in all areas of professional education at the University of Hong Kong.

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Appendix A

PROFILES OF STUDENTS

SPQ Profile

Computing skills

Buzan mind map

Pfnet

Mental model of server

Results

NAME:

Alice

GROUP:

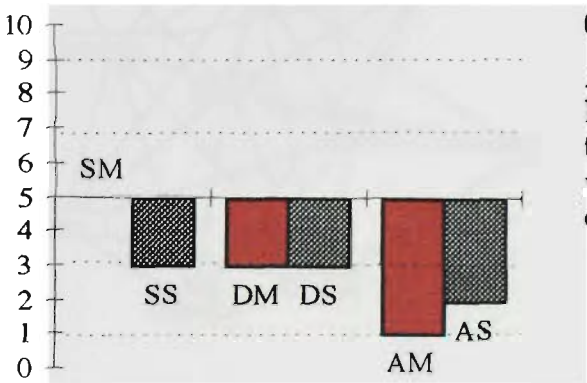
Temple — Base

ORIGIN:

University of Hong Kong

SPQ PROFILE

COMMENTS

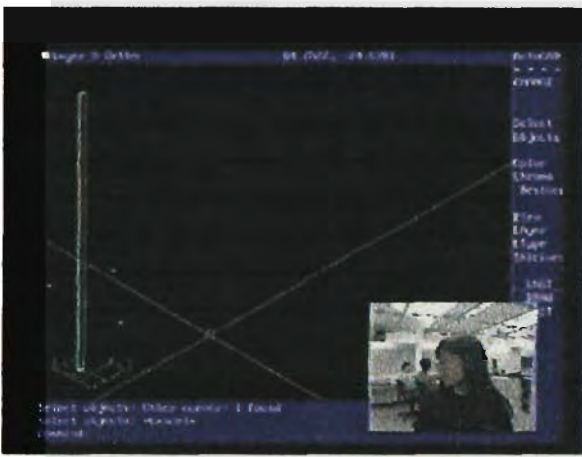


0 0 | 0 0 | - 0

A fairly average profile, Surface and Deep scores are at the lower end of typical. Achieving scores are low, but not unusually so in comparison with the class.

3D EXERCISE

COMPUTING SKILL



Declarative Low

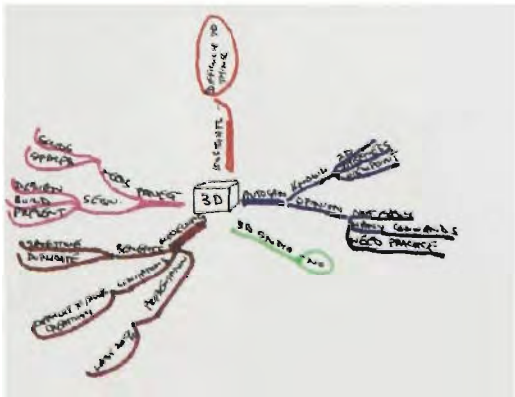
Procedural Average

Contextual Low

Able only to draw a tall, thin (pencil-like) object. No control over parameters and could not find multiview.

COMPUTING MIND MAP

COMMENTS

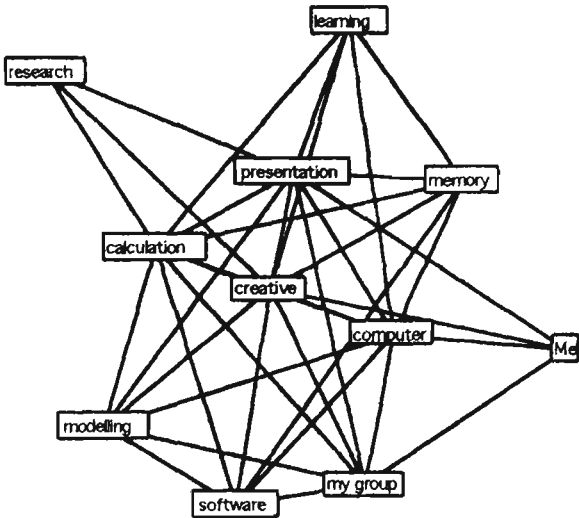


Shows limited knowledge of AutoCAD and few opinions. Finds it "difficult to think in front of a computer"

Has a fair idea of how the computer will be used in the project.

PROFILE: Alice (cont.)

PFnet



COMMENTS

PATTERN: Cat's cradle

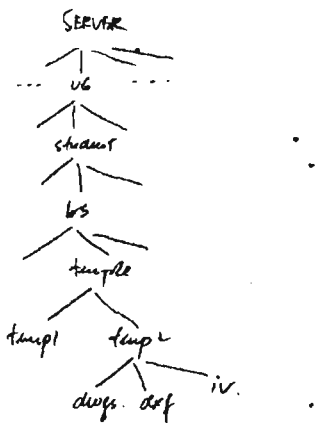
Alice has little use for computer modelling software and values group work and creativity.

Scored almost all pairs between 1-3. This inevitably produces many links. Her only 5+ ratings were:

research-presentation-calculation and *me- group- creative- presentation* (computer is linked through *presentation*).

The *creative-computer* link she explains as "other people are creative with the computer".

MENTAL MODEL OF SERVER



COMMENTS

ACCURACY: 3

SHAPE: Hierarchical, bs

Displays a rudimentary knowledge of the path from the root level to the Temple sub-directories. Not aware of what else is on the server or where the applications reside.

RESULTS BS1

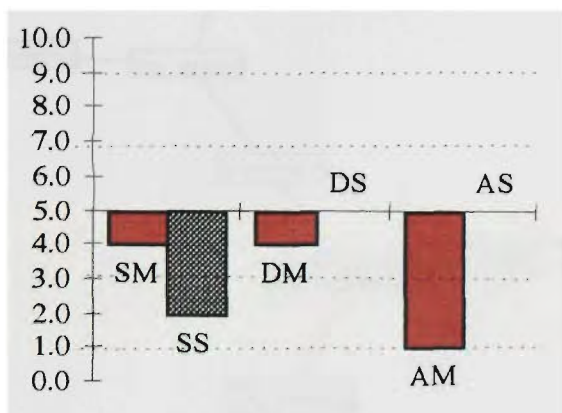
C

RESULTS M.ARCH

B

NAME: Bonita
GROUP: Temple — Dau-Gung
ORIGIN: University of Hong Kong

SPQ PROFILE



COMMENTS

$$0 - | 00 | - 0$$

Low on surface strategy and achieving motive — fairly typical of the class in her approach to learning

3D EXERCISE



COMPUTING SKILL

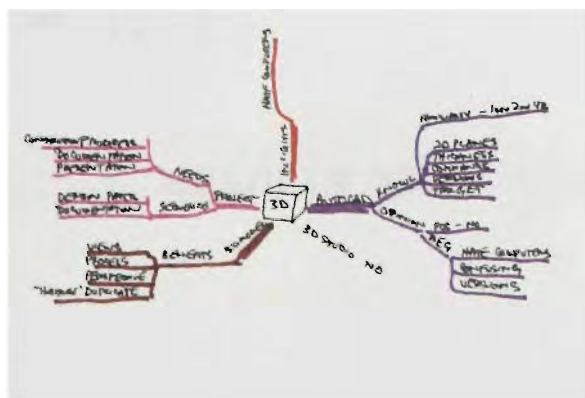
[illegible]

Procedural Low

Contextual Low

Was only able to draw a 2D shape.

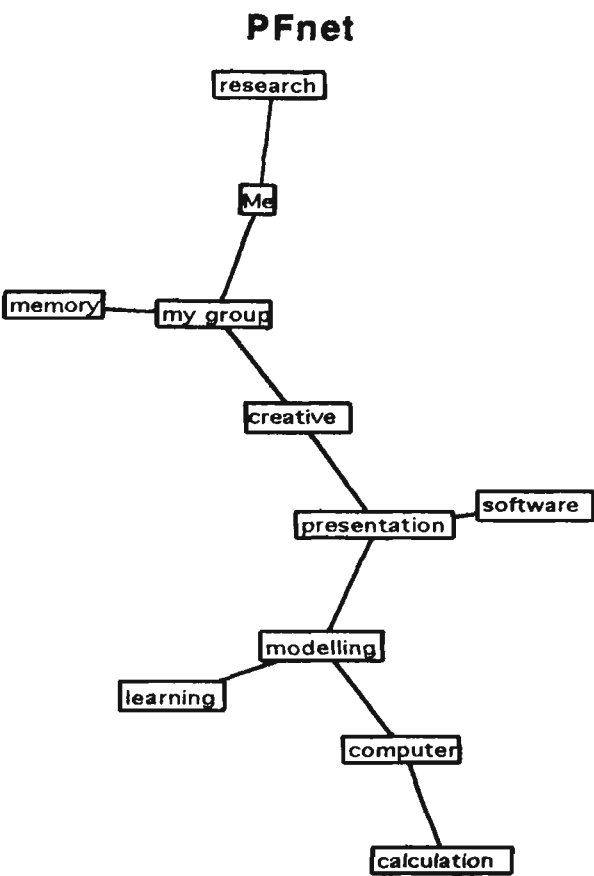
COMPUTING MIND MAP



COMMENTS

Displays reasonable declarative knowledge of AutoCAD only. Was able to list some benefits of modelling and discuss the use of computing in the project.

PROFILE: Bonita (cont.)



COMMENTS

PATTERN: Branching

Bonita dislikes computers and relates them only to calculation and 3D modelling. There are two sets of linked concepts in her PFnet

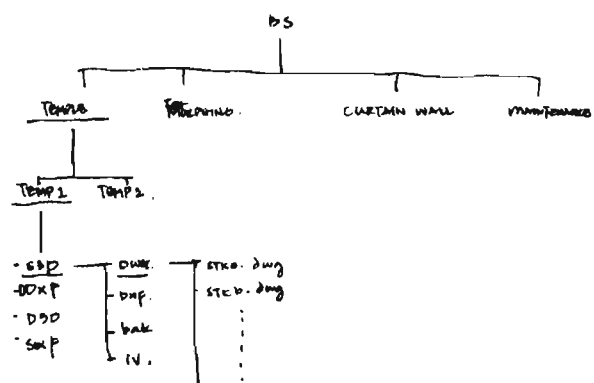
presentation/modelling — which are linked to *creative, software, computer & learning*; and

group which is linked to *creative, memory & me*.

It is interesting that she relates *memory* closely to *group* — an affirmation of the importance of distributed cognition in project work. Bonita accepts that the modelling project was a significant learning experience.

MENTAL MODEL OF SERVER

COMMENTS



ACCURACY: 4

SHAPE: Hierarchical, bs

Displays a rudimentary knowledge of the path from the bs level to the Temple sub-directories and some detail at that level.

RESULTS BS1

RESULTS M.ARCH

NAME:

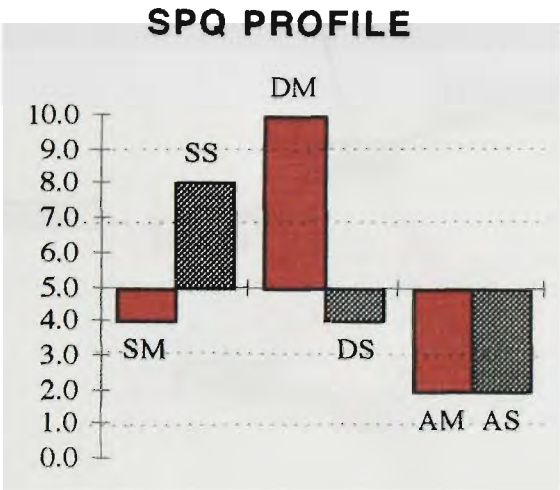
Christina

GROUP:

Curtain Wall

ORIGIN:

University of Manitoba

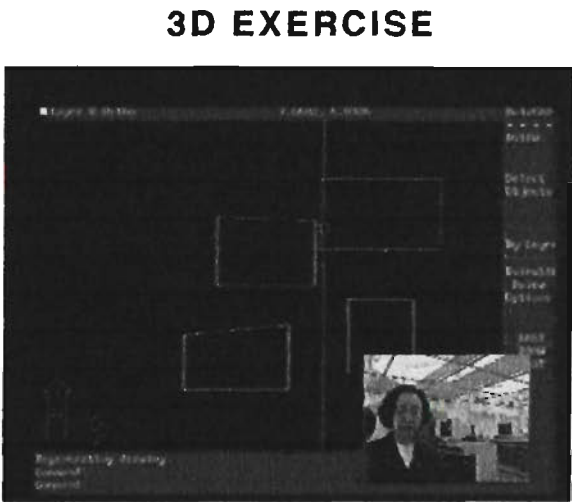


COMMENTS

0 + | + 0 | - -

A combination of high surface strategy and deep motive indicates a committed student, but uncertain about what is required of the course.

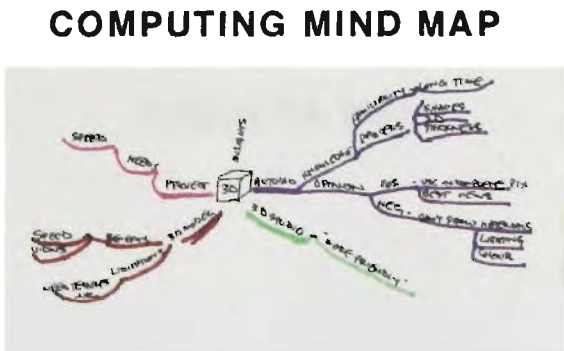
Low achieving score is not an accurate reflection of her performance in the course



COMPUTING SKILL

Declarative	Low
Procedural	Average
Contextual	Average

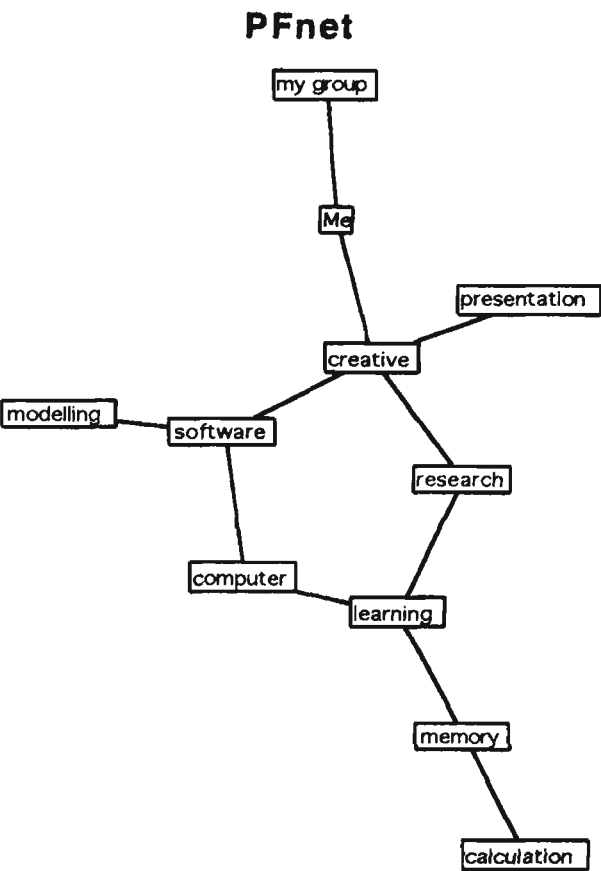
Could use the software, but was only able to create rudimentary 3D shapes



COMMENTS

Had a lot to say about AutoCAD and its drawbacks compared to hand drawing. Found 3D Studio more friendly. Reasonable contextual knowledge of computers and architecture

PROFILE: Christina (cont.)



COMMENTS

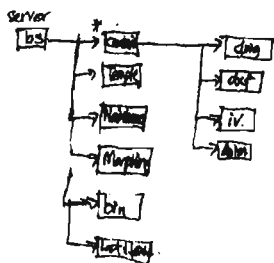
PATTERN: Branching

The concept with the largest number of links for Christina is *creative* — linked to *me*, *presentation*, *research* & *software*. This accords with her belief that architecture is a creative profession and the BS1 course was sometimes forcing her to be a technician.

Learning is linked to *computer* (“I spent a lot of time learning computing”) as well as *research* and *memory* (she complains that there is too much emphasis on memorization in HKU courses)

The simple and well-structured PFnet reinforces the evidence from the data that Christine developed clear and well-considered views on the relationships between computers, project work and learning.

MENTAL MODEL OF SERVER



COMMENTS

ACCURACY: 4

SHAPE: Hierarchical, bs

Rudimentary model of server from “bs” node downwards. Was unaware of what else was on the server, only where her files were stored. (Often had difficulty as there were several “bs” nodes.)

RESULTS BS1

A

RESULTS M.ARCH

B

NAME:

GROUP:

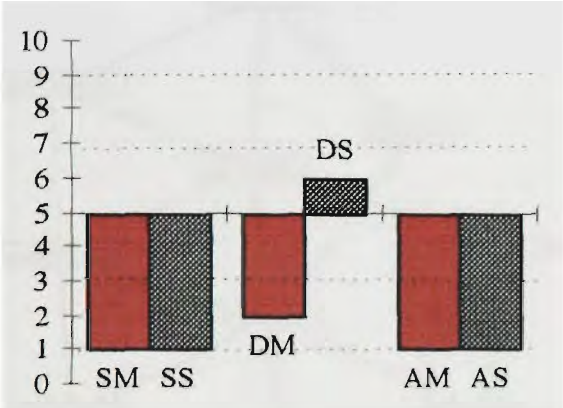
ORIGIN:

Desmond

Temple — Dau-gung

University of Hong Kong

SPQ PROFILE

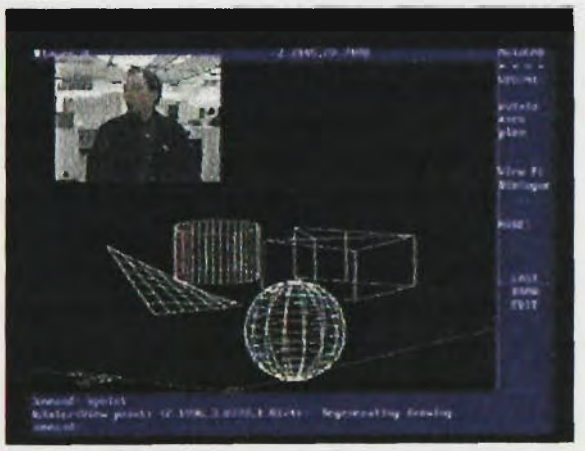


COMMENTS

-- | - 0 | --

Desmond is well below average on all scales other than Deep Strategy. May indicate low metacognitive awareness.

3D EXERCISE



COMPUTING SKILL

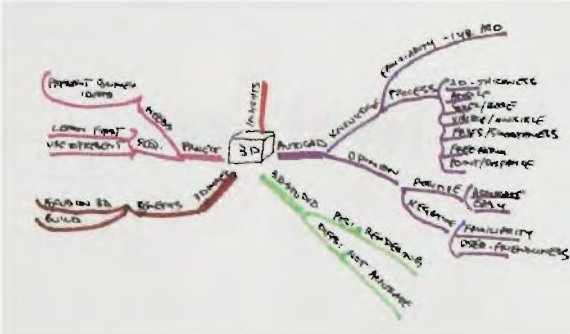
Declarative High

Procedural High

Contextual High

Highly skilled AutoCAD operator, able to produce a variety of complex 3D shapes

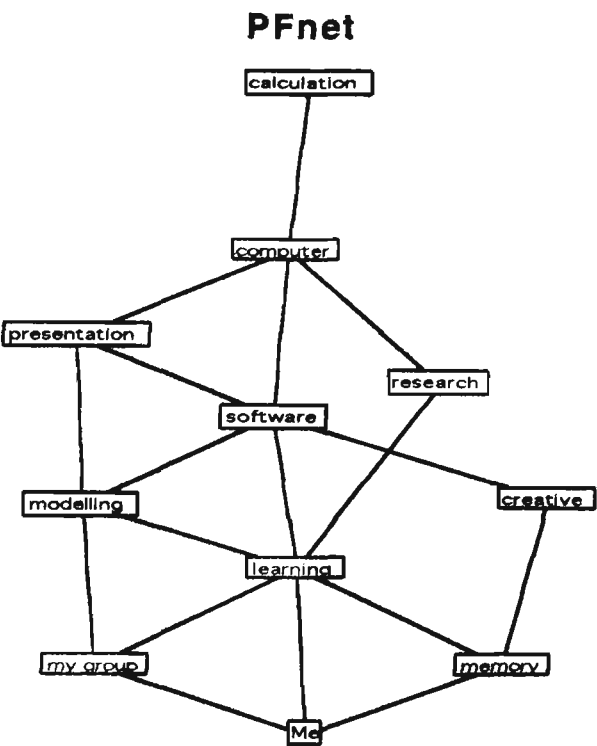
COMPUTING MIND MAP



COMMENTS

Shows a high degree of declarative knowledge on AutoCAD and comparative opinions on 3D Studio. A little weak on contextual knowledge in this interview.

PROFILE: Desmond (cont.)



COMMENTS

PATTERN: Web (2 foci)

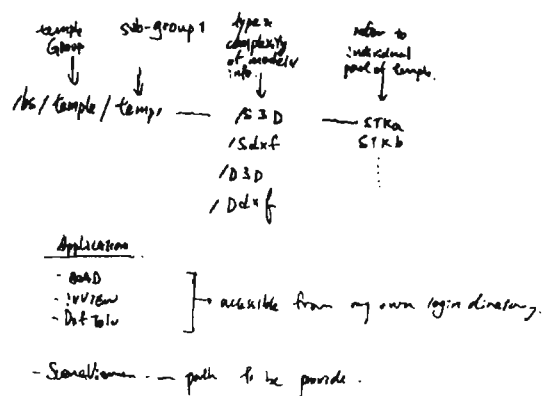
Desmond’s PFnet very clearly reflected his interests: he was principally responsible for developing the highly complex dau-gung models.

Computer is closely linked to technical issues — *calculation, presentation & research*; and these are linked through *software* and *research* to *learning*. The series of triangular relationships in the lower half of the net are accurate reflections of the course structure:

learning - software - modelling
learning - modelling - group
learning - group - me
learning - me - memory, etc.

MENTAL MODEL OF SERVER

COMMENTS



ACCURACY: 4

SHAPE: Explanatory, bs

Desmond’s model may not be a good example of visual communication, but it contains all the necessary information to use the system. He indicates where the main applications are located and includes an explanatory gloss.

RESULTS BS1

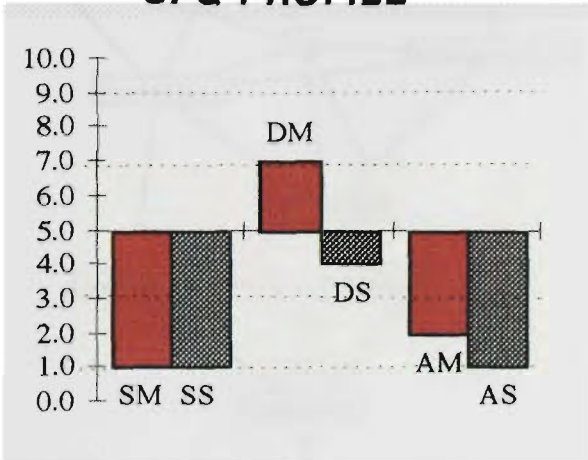
RESULTS M.ARCH

B

C

NAME:	Fai
GROUP:	Curtain Wall
ORIGIN:	University of Hong Kong

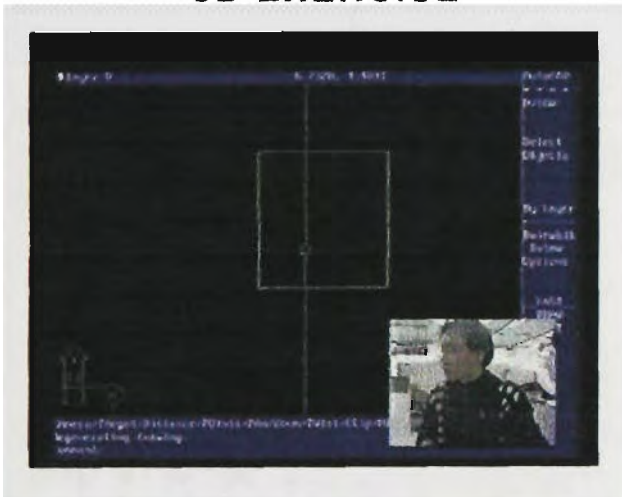
SPQ PROFILE



COMMENTS

-- | 0 0 | --
The low surface and average deep scores are typical for the class. Fai’s very low achieving approach reflects his concerns about succeeding in the course (also fairly typical).

3D EXERCISE

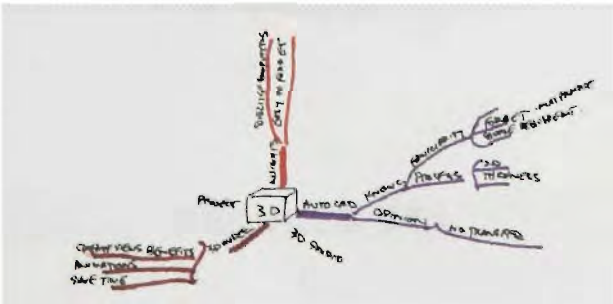


COMPUTING SKILL

- Declarative Low
- Procedural Low
- Contextual Low

Found great difficulty opening and operating AutoCAD and only succeeded in drawing a square.

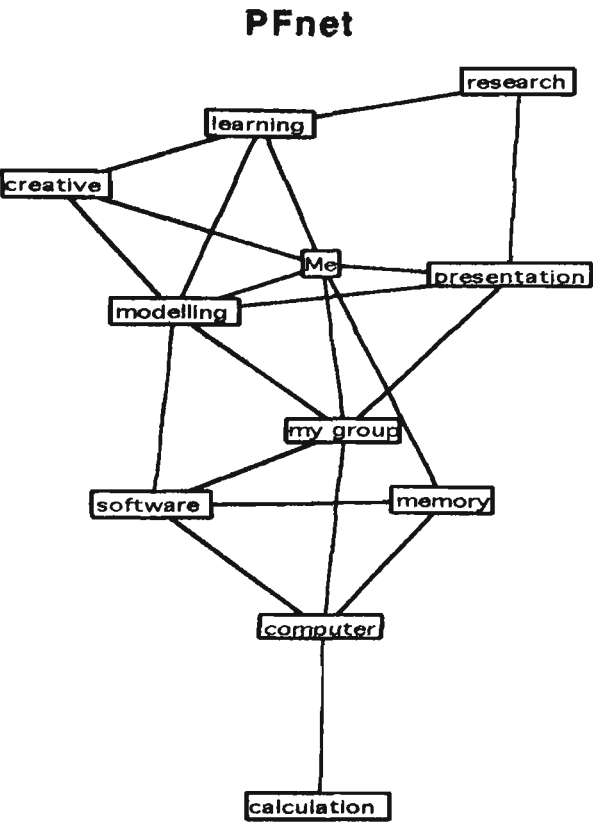
COMPUTING MIND MAP



COMMENTS

Almost no declarative knowledge evident apart from some rudimentary commands. Very few opinions bout software. Dislikes computers

PROFILE: Fai (cont.)



COMMENTS

PATTERN: Web (2 overlapping foci)

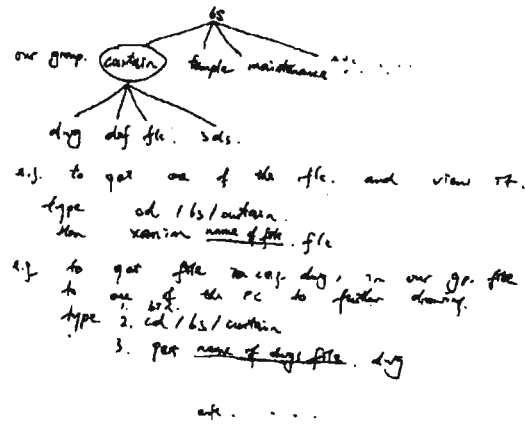
The PFnet shows *me* and *group* as central concepts. Me is linked to *learning*, *creative*, *modelling* and *presentation*; group shares *modelling* and *presentation* and is linked to *software* and *computer*.

Memory is linked both to *me* ("my memory") and *computer* (RAM)

Fai's relationship with computing only exists through the *group* and the *presentation* exercise.

Concepts such as *learning* and *creativity* are unrelated to computing.

MENTAL MODEL OF SERVER



COMMENTS

ACCURACY: 3

SHAPE: Explanatory, bs

Basic tree from "bs" down only.

Finds it more comfortable to write instructions on how to retrieve files than to map the path:

"e.g. to get one of the flc and view it
type: cd /bs /curtain, then
xanim name of file.flc"

RESULTS BS1

C

RESULTS M.ARCH

C

NAME:

GROUP:

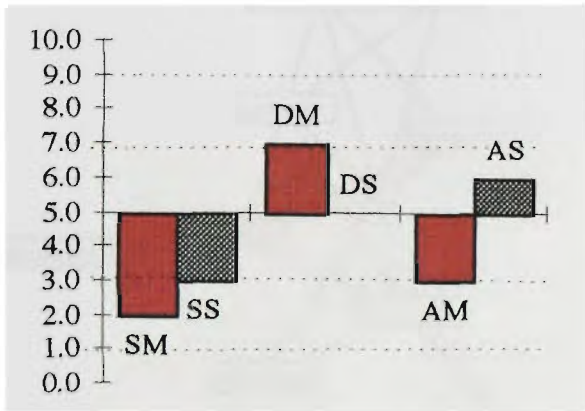
ORIGIN:

Frankie

Curtain Wall

University of Hong Kong

SPQ PROFILE

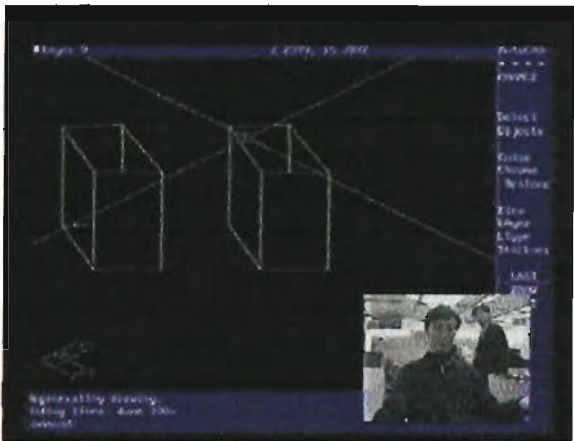


COMMENTS

- 0 | 0 0 | 0 0

Low surface motivation, high-average deep motivation, a fairly typical profile.

3D EXERCISE



COMPUTING SKILL

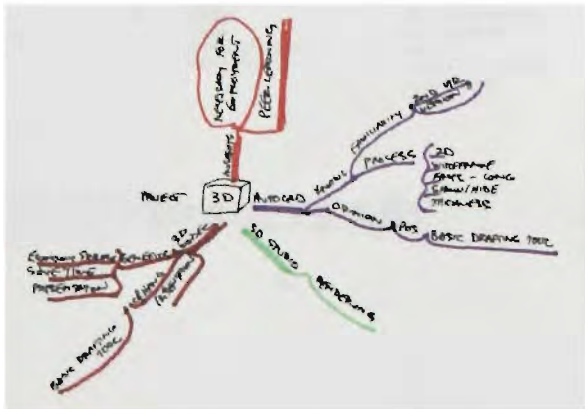
Declarative Average

Procedural Average

Contextual Average

Was able to draw some basic 3D wire-frame shapes, but could not activate the multiview.

COMPUTING MIND MAP

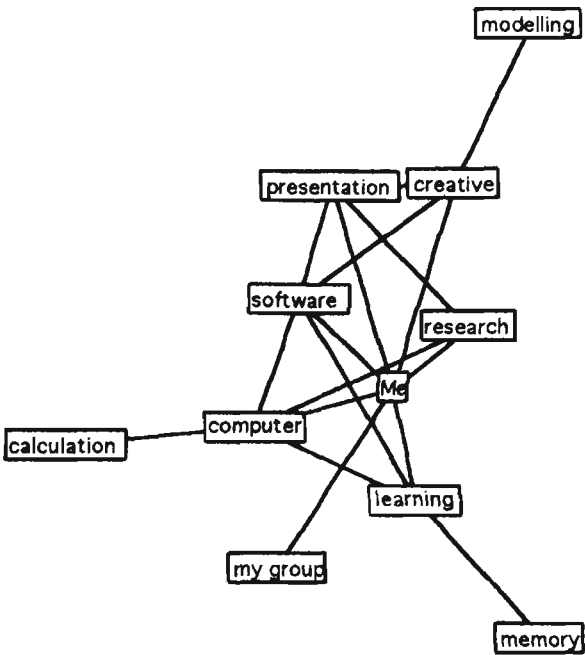


COMMENTS

Displays reasonable declarative knowledge of AutoCAD and that 3DS is better for rendering. Quite a few opinions about benefits & drawbacks. Believes it necessary for employment. Will learn from friends

PROFILE: Frankie (cont.)

PFnet



COMMENTS

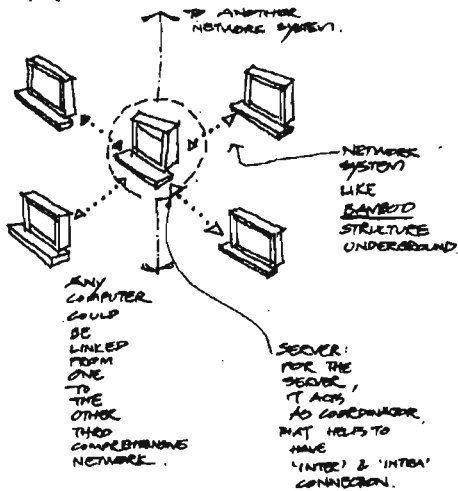
PATTERN: Web

Me is the central concept in Frankie's PFnet, and is directly related to everything except *calculation*, *modelling* and *memory* — none of which he enjoys. The arrangement of triangular relationships around the central concept reflect very clearly the structure of the BS1 experience:

me - learning - computer
me - computer software
me - software - presentation
me - software - learning
me - presentation - creative
me - presentation - research
me - research - computer

The net suggests a student with well-defined views of how the world works and his place within it.

MENTAL MODEL OF SERVER



COMMENTS

ACCURACY: 2

SHAPE: Representational

The most artistic of all the models. Unfortunately it is not particularly meaningful. Frankie has drawn a schematic diagram of the computer lab, not a mental model of the server.

(An apposite Asian simile for the system cabling "like bamboo structure underground")

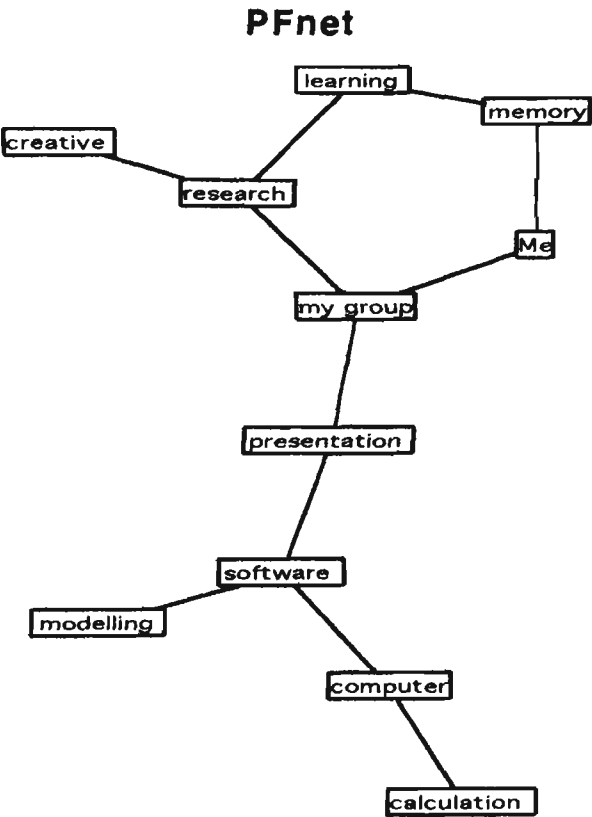
RESULTS BS1

C

RESULTS M.ARCH

B

PROFILE: Han (cont.)



COMMENTS

PATTERN: Branching

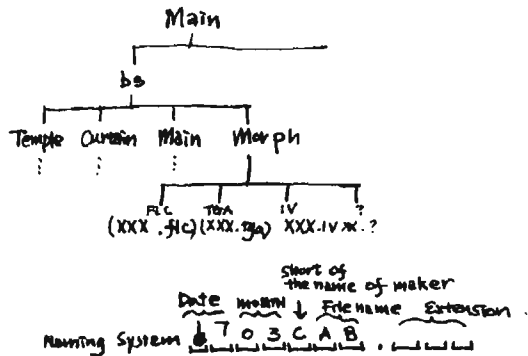
Han’s PFnet almost exactly matches the “class average” net calculated by KNOT and is an accurate reflection of the BS1 experience:

The “personal” concepts *me*, *group*, *memory*, *learning* & *creative* are linked to the “computing” concepts *software*, *computer*, *modelling* & *research* through the concept *presentation*.

Research is closely linked to *group*, *creative* & *learning* (a strong graphic representation of constructivist learning and distributed cognition.)

The clearly defined relationships of the net reflect Han’s well-structured approach to study and design work, which earned her high marks in Year 4.

MENTAL MODEL OF SERVER



COMMENTS

ACCURACY: 5

SHAPE: Hierarchical, Root

A well-structured and clear tree from Root level, which includes an explanation of the code the Morphing group developed for keeping track of files.

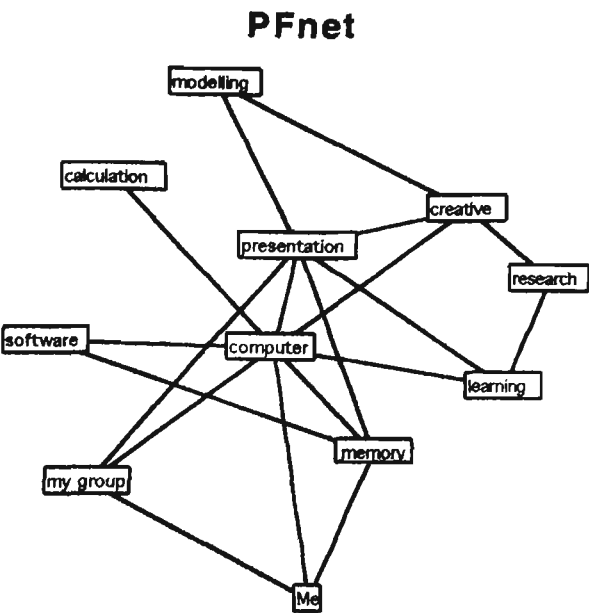
RESULTS BS1

A

RESULTS M.ARCH

C

PROFILE: Howard (cont.)



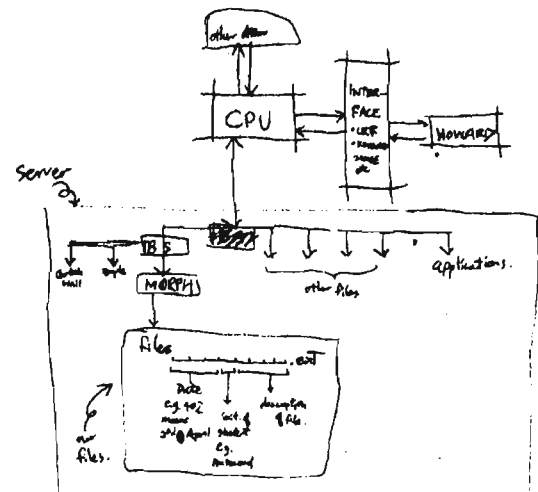
COMMENTS

PATTERN: Web (2 overlapping foci)

Howard was one of the leaders in computing and was in charge of developing the morphing system. The PFnet is a clear representation of his concept of the BS1 course, with *computing & presentation* the central concepts and a set of indicative triangular relationships:

- computer - me - group*
- computer - group - presentation*
- computer - presentation - learning*
- computer - presentation - creative*
- computer - memory - me (my memory)*
- computer - memory (RAM)- software*
- presentation - creative - modelling, and*
- presentation - creative - research - learning*

MENTAL MODEL OF SERVER



COMMENTS

ACCURACY: 5

SHAPE: Hierarchical, Root

A complex schematic which, in addition to the server structure, includes the hardware (CPUs, interfaces) and the user (Howard).

It also includes an explanation of the code the morphing group developed to keep track of their files.

RESULTS BS1

B

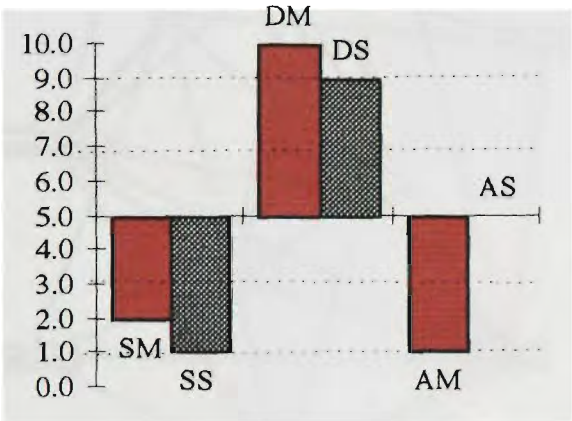
RESULTS M.ARCH

C

NAME:	Joan
GROUP:	Maintenance
ORIGIN:	University of Sydney

SPQ PROFILE

COMMENTS



-- | ++ | - 0

Extremely high scores on deep approach are not matched by achieving strategies. Joan is often in danger of losing her way among fascinating side issues.

3D EXERCISE

COMPUTING SKILL



Declarative Low

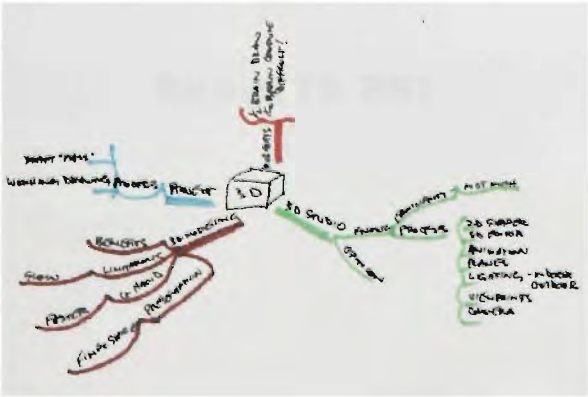
Procedural Low

Contextual Low

Chose to demonstrate 3DS because she thought it more friendly than AutoCAD. Only succeeded in drawing 2D shapes.

COMPUTING MIND MAP

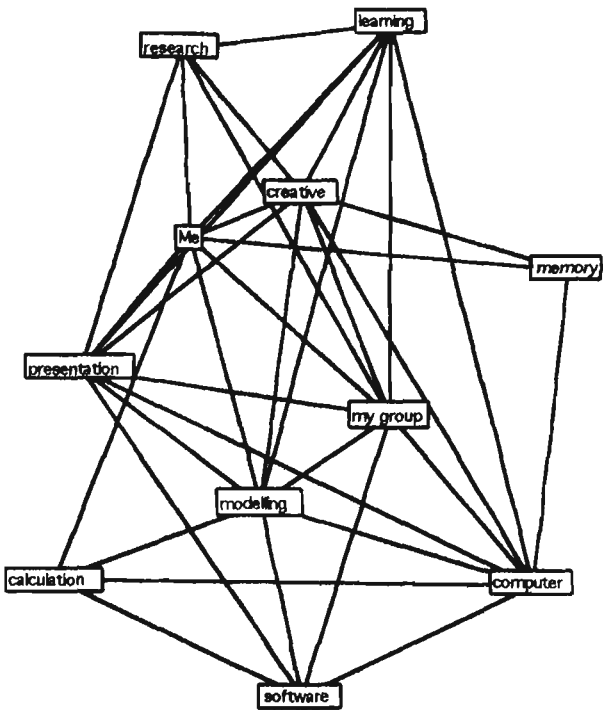
COMMENTS



A reasonable amount of declarative (vocabulary) knowledge of 3DS and some opinions on the value of modelling. Does not enjoy working with computers

PROFILE: Joan (cont.)

PFnet



COMMENTS

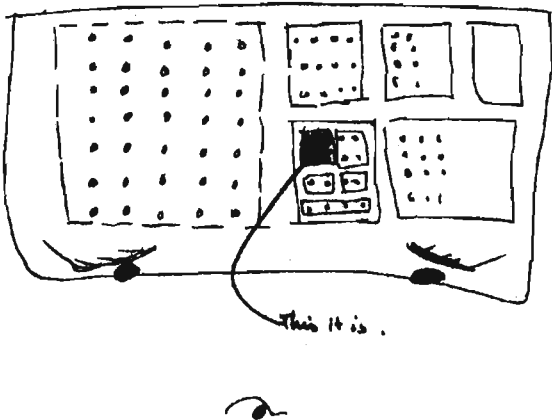
PATTERN: Cat's cradle

For Joan everything is related. She is a person who is fascinated by connections and side-issues and the PFnet reflects this. The only concept with less than 5 links is *memory* (3 links),

Me is linked to everything except *software* and *computer* — a reflection of her views about computing and architecture.

Joan began the course disliking computers, but her continuing alienation is rather surprising considering how skillful she became at AutoCAD over the 18 months of the study.

MENTAL MODEL OF SERVER



COMMENTS

ACCURACY: 1

SHAPE: Fanciful

An attempt to anthropomorphize (humanize?) the computer. In terms of file structure it is meaningless; in terms of Joan's attitudes to computing it is revealing.

RESULTS BS1

C

RESULTS M.ARCH

B

NAME:

GROUP:

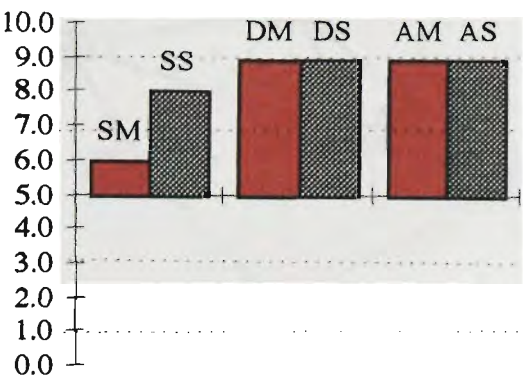
ORIGIN:

Leung

Temple — Base

British training + 9 years in the work force

SPQ PROFILE



COMMENTS

0 + | + + | + +

Extremely high deep-achieving student, reflecting strong motivation and self-knowledge. The high surface scores possibly reflect uncertainty about the requirements of the course (returning to study after a long absence)

3D EXERCISE



COMPUTING SKILL

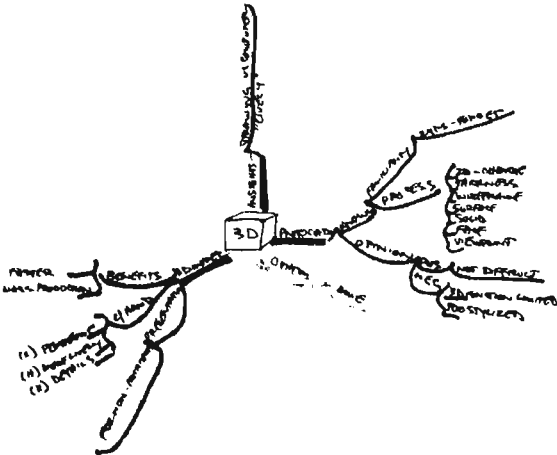
Declarative Average

Procedural Average

Contextual High

Could not control parameters or use multiview. Succeeded only in drawing a long thin 3D polygon.

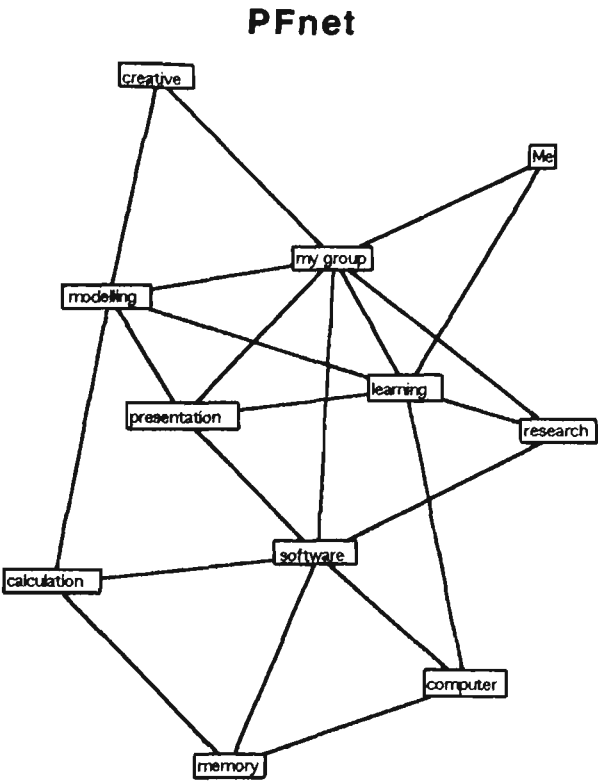
COMPUTING MIND MAP



COMMENTS

Reasonable declarative (vocabulary) knowledge. Unfamiliar with any software other than AutoCAD. High level of contextual knowledge. Finds hand drawing “more lively”

PROFILE: Leung (cont.)



COMMENTS

PATTERN: Web (3 foci)

Support from the group was obviously very important for Leung.

The pattern is typical of someone who has clearly formulated views about BS1 as a learning experience.

Learning is linked to me, group, modelling, presentation & computer.

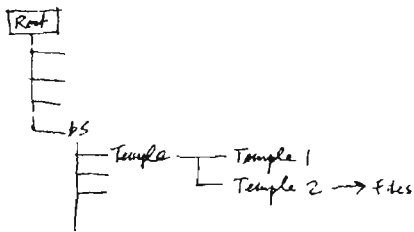
The interviews demonstrate Leung’s strong commitment to design and aesthetics —computing is not strongly linked to either.

Me & creative are 2-3 links away from computer.

Software, calculation, memory (RAM) & computer form a separate and distinct group of linked relationships.

MENTAL MODEL OF SERVER

COMMENTS



ACCURACY: 3

SHAPE: Hierarchical, Root

Simple (oversimplified) model which is not very accurate. Not familiar with networked computing.

RESULTS BS1

RESULTS M.ARCH

B

C

NAME:

Mo

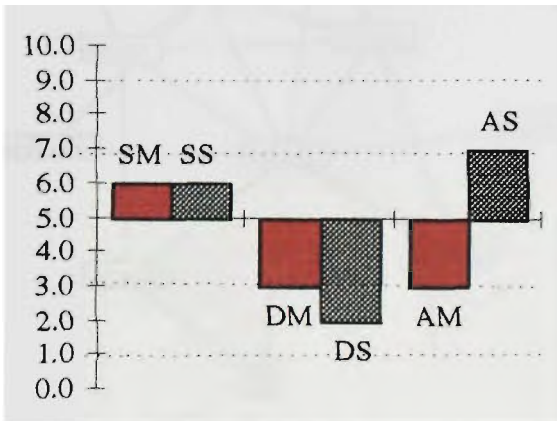
GROUP:

Maintenance

ORIGIN:

University of Hong Kong

SPQ PROFILE

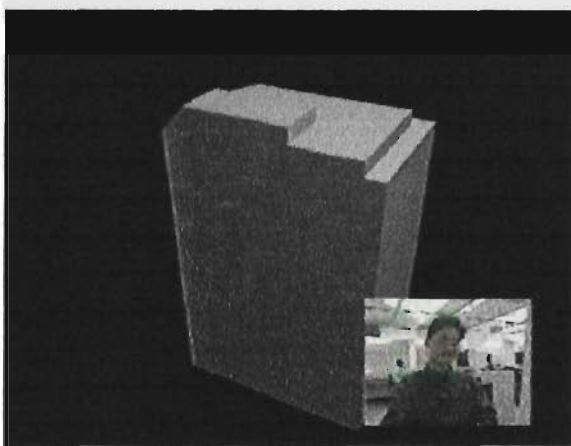


COMMENTS

00 | 0 - | 00

Low scores in deep approach reflect Mo's often expressed attitude to "just getting through"; however he spent more time than most in complex modelling work and produced high quality work.

3D EXERCISE



COMPUTING SKILL

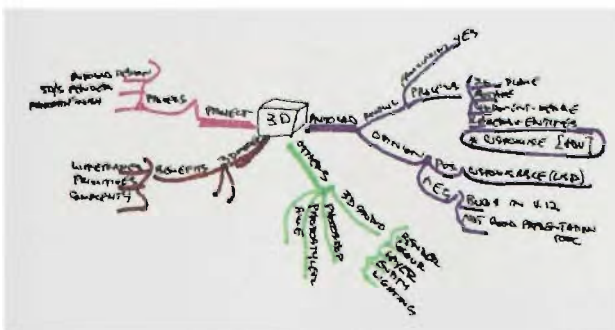
Declarative High

Procedural High

Contextual High

Mo was able to produce a shape in AutoCAD then port it to 3DS for rendering. Extremely high computing skills.

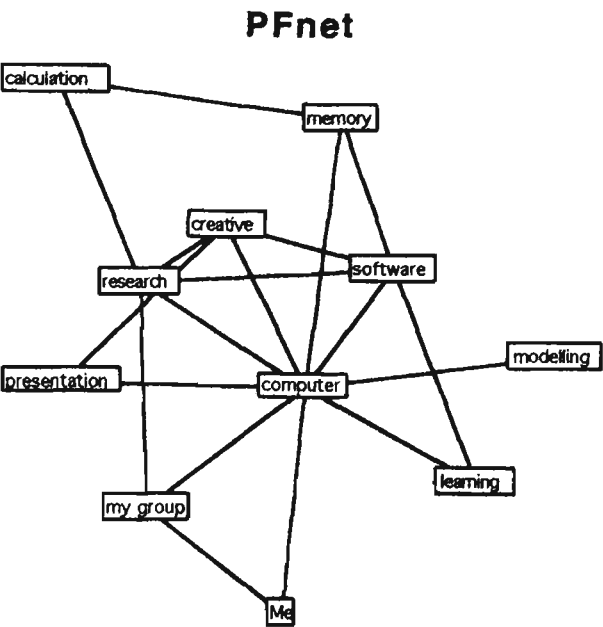
COMPUTING MIND MAP



COMMENTS

Shows comprehensive knowledge of two software and mentions several others. Is aware of ways of customizing AutoCAD. High contextual knowledge.

PROFILE: Mo (cont.)



COMMENTS

PATTERN: Web

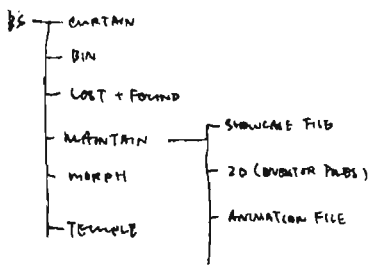
Mo’s PFnet is a textbook image of someone for whom *computing* is the central concept. Everything is directly related to it except calculation (“Why would you use a computer when you can use a calculator?”)

Mo was surprised to find how accurately the image reflected his position.

One interesting aspect of this net is the links which are not present: *me* and *group* are not linked to *presentation*, nor to *modelling*. Mo was not a happy member of his group and often complained that there was no leadership or coordination, which left him doing all the hard work.

MENTAL MODEL OF SERVER

COMMENTS



ACCURACY: 3

SHAPE: Hierarchical, bs

Simplified but accurate tree including sub-directories of Maintenance group. (Mo also included a list of 8 additional applications — not included due to lack of space)

RESULTS BS1

RESULTS M.ARCH

B

C

NAME:

Ronald

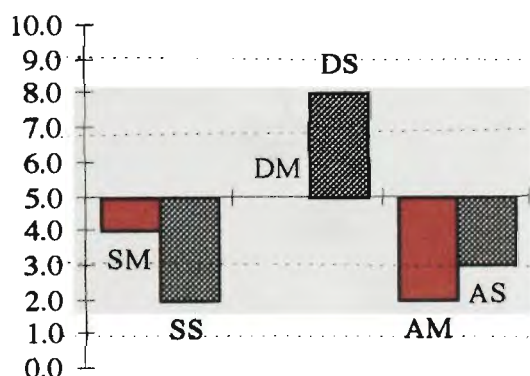
GROUP:

Temple — Base

ORIGIN:

Tamkan University (Taiwan)

SPQ PROFILE

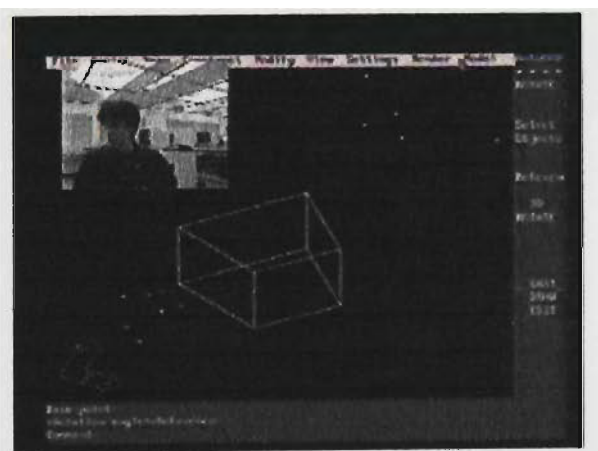


COMMENTS

$$0 - 1 \quad 0 + 1 - 0$$

Ronald's deep strategy became a liability when combined with low achieving approach — it meant that he was often behind schedule and failed several subjects because of late submissions.

3D EXERCISE



COMPUTING SKILL

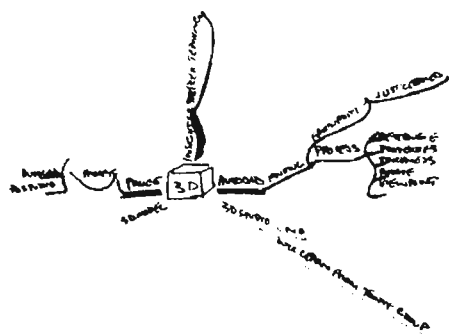
Declarative Low

Procedural	Average
------------	---------

Contextual Low

Was able to create a basic 3D shape, but was unsure of the meaning of the white points. Could not open multiview

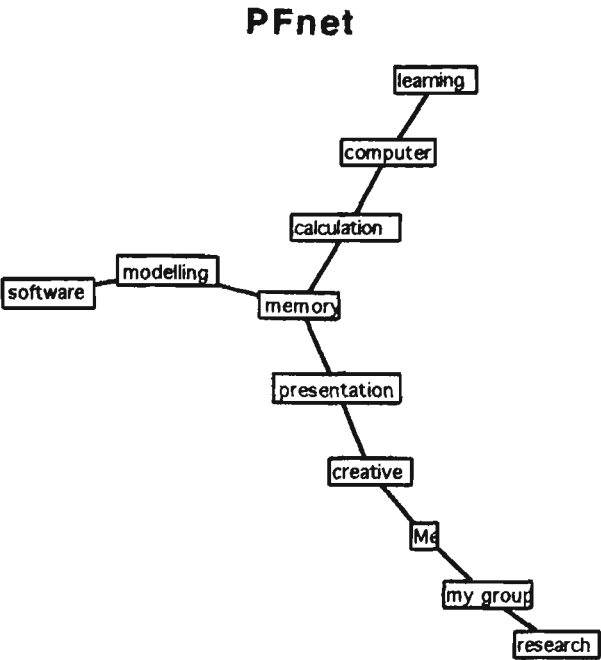
COMPUTING MIND MAP



COMMENTS

Very little declarative knowledge evident. Few opinions or contextual knowledge.. Proposes to learn computer skills from classmates

PROFILE: Ronald (cont.)



COMMENTS

PATTERN: Linear (3 strands)

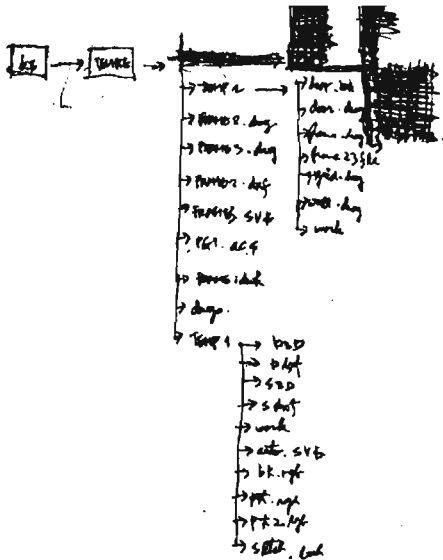
Ronald took more than 40 minutes to complete the KNOT exercise, so every score is carefully considered.

The result is intriguing: *me* is placed far from the centre, linked only to *group* and *creative*; *computer* is 5 links away, and *learning* is as far from *me* as it is possible to go.

For someone with such low SPQ scores on *surface* and high scores in *deep* it is surprising that Ronald makes memory his only central concept. However, the PFnet was done at the end of the course when he was under a great deal of stress having failed two subjects because of non-submission of work. Memorizing was possibly a last resort.

MENTAL MODEL OF SERVER

COMMENTS



ACCURACY: 2

SHAPE: Hierarchical, bs

A “bottom-up” map, showing the location of every file in his group’s sub-directory. However, there is no indication that Ronald knows where anything else is located on the server or where these files are in relationship to other groups’ work.

RESULTS BS1

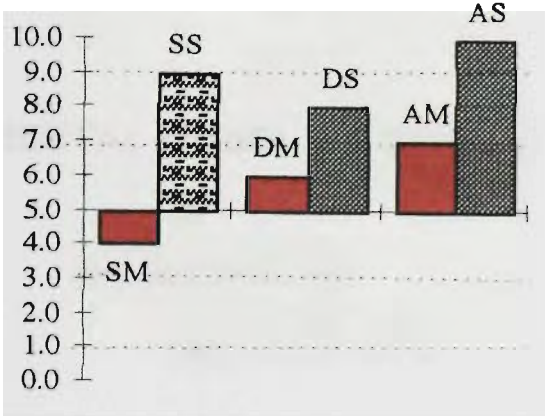
RESULTS M.ARCH

D

Repeat 2 subjects

GROUP: 
ORIGIN: 

SPQ PROFILE

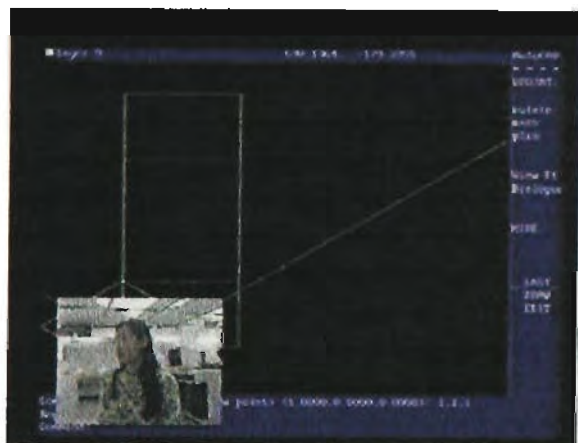


COMMENTS

0 + | 0 + | 0 +

Extremely high surface, deep and achieving strategies indicates a student determined to succeed no matter how she does it.

3D EXERCISE



COMPUTING SKILL

Declarative	<i>Average</i>
--------------------	----------------

Procedural	Average
------------	---------

Contextual Average

Was able to draw a basic 3D shape, but could not open the multiview

COMPUTING MIND MAP



COMMENTS

Shows a basic declarative knowledge of AutoCAD and is aware of properties of other software. Basic contextual knowledge

PROFILE: Shirley (cont.)

PFnet

COMMENTS

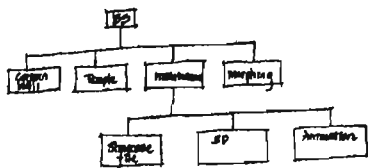
Not available

Shirley was not available to do a PFnet as she had left the university.

In spite of her strong SPQ strategy scores, she failed one subject in her final year and had to repeat it.

MENTAL MODEL OF SERVER

COMMENTS



ACCURACY: 3

SHAPE: Hierarchical, bs

Basic structural knowledge of tree, showing relationship of Maintenance files to other groups.

RESULTS BS1

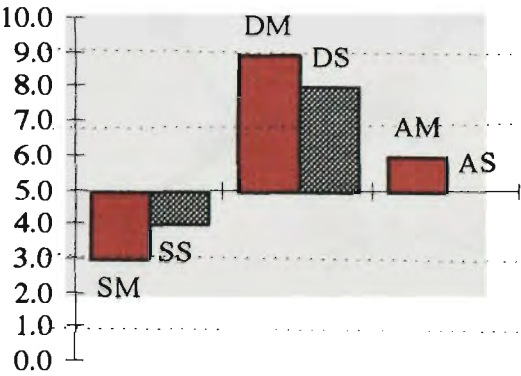
RESULTS M.ARCH

C

C

NAME:	Wai (a.k.a. Michael)
GROUP:	Curtain Wall
ORIGIN:	University of Hong Kong

SPQ PROFILE



COMMENTS

0 0 | + + | 0 0

A highly motivated student with extreme high scores on deep motive and strategy. The achievement score does not reflect his considerable ambition and highly-developed study skills.

3D EXERCISE



COMPUTING SKILL

Declarative High

Procedural High

Contextual High

Used 3D Studio to draw and render a series of complex shapes

COMPUTING MIND MAP

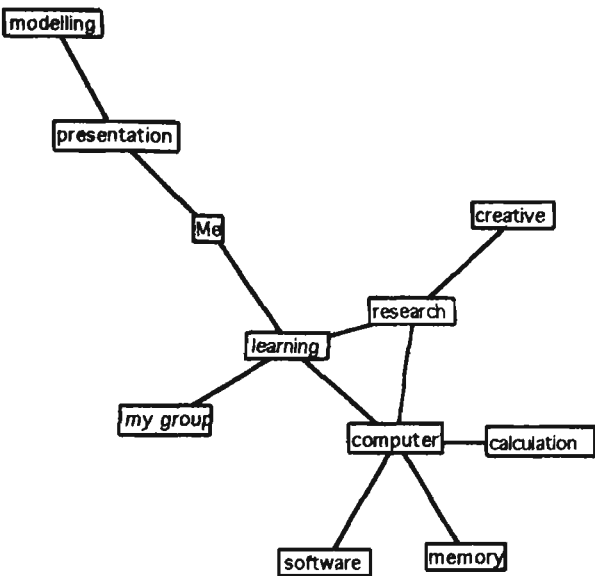


COMMENTS

Reflects a high level of declarative and contextual knowledge of 3DS in particular and computer modelling in general.

PROFILE: Wai (cont.)

PFnet



COMMENTS

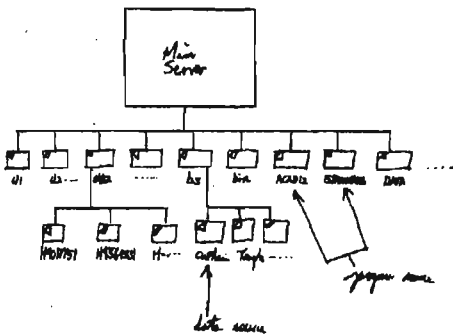
PATTERN: Branching

Like all the highly skilled computer performers, *computer* is the focus concept with the largest number of links; *learning* is second most linked concept with connections to *me*, *group*, *research* & *computer*.

In the upper branch *modelling* is 4 links away from computing, possibly due to the fact that in the previous semester Wai had been involved in constructing an elaborate physical model to simulate the effects of sunlight.

Wai was the top student in the course.

MENTAL MODEL OF SERVER



COMMENTS

ACCURACY: 5

SHAPE: Hierarchical, Root

A detailed and accurate schematic diagram of the server, showing both application and file locations. Indicates a high level of structural knowledge.

RESULTS BS1

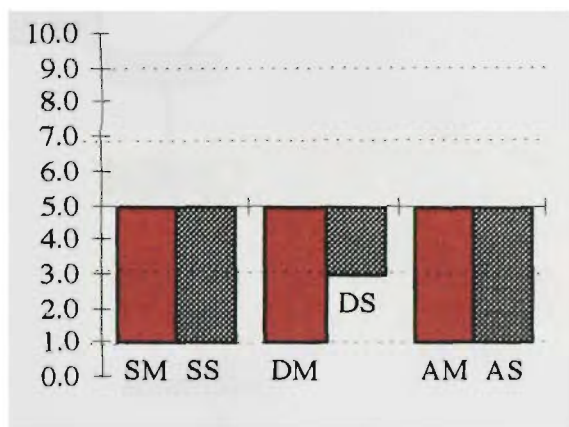
A

RESULTS M.ARCH

A

NAME:	Wai-man
GROUP:	Morphing
ORIGIN:	University of Hong Kong

SPQ PROFILE



COMMENTS

- - | - 0 | - -

Such low scores in all areas would seem to indicate a student who denies any value in learning. Yet Wai-man was a successful, contributing — if self-effacing — student.

3D EXERCISE



COMPUTING SKILL

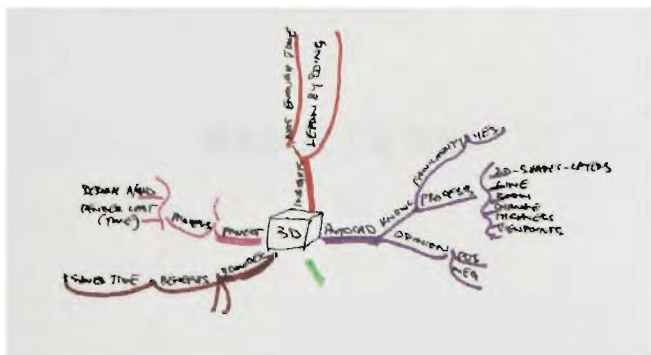
Declarative High

Procedural	Average
------------	---------

Contextual Low

A competent AutoCAD user. She was able to produce several basic 3D shapes. Could not use multiview.

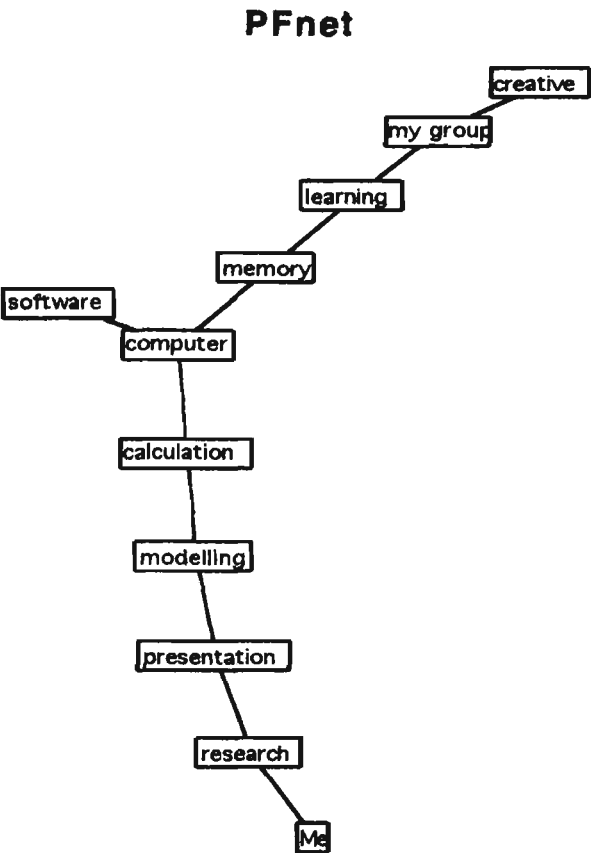
COMPUTING MIND MAP



COMMENTS

A reasonable degree of declarative knowledge (interviews include a great deal of vocabulary knowledge). Low contextual knowledge displayed,

PROFILE: Wai-man (cont.)



COMMENTS

PATTERN: Linear (2 strands)

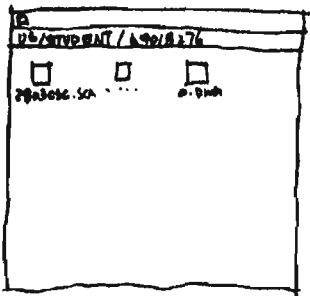
Me is at one end of the net, *creative* is nine links away at the opposite end. It seems surprising that *group* is so far from *me* as Wai-man was a popular and contributing member of the Morphing group.

The net makes more sense if one follows the links outwards from the centre (Wai-man is a competent computer user). The lower path: *computer* - *calculation* - *modelling* - *presentation* - *research* - *me* ... reflects her work with Howard on the highly complex job of producing the morphing structures.

The upper path: *computer* - *memory* - *learning* - *group* - *creative* ...is how she sees the other members of the group: being creative and learning a lot.

She is, through the PFnet, denying her contribution; which is reflected in the "denying" SPQ score from 18 months earlier.

MENTAL MODEL OF SERVER



COMMENTS

ACCURACY: 1

SHAPE: Fanciful

Shows the SGI login screen with Wai-man's ID number and three files.

RESULTS BS1
C

RESULTS M.ARCH
C

PROFILE: William (cont.)

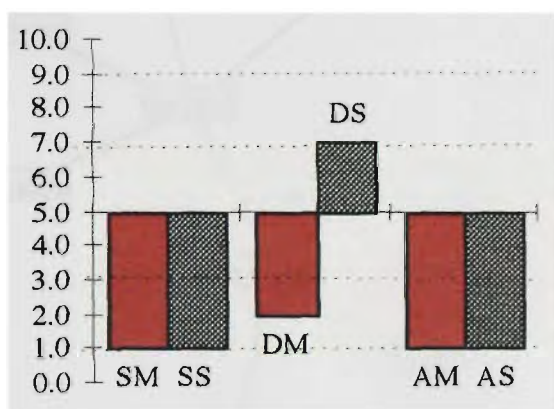
PFnet	COMMENTS
Not available	William was Malaysian Chinese and found living and working in Hong Kong very difficult. He fell behind in 4th Year and did not submit his final design project. This means he failed the course and will have to repeat.

MENTAL MODEL OF SERVER	COMMENTS
Not available	William was absent.

RESULTS BS1	RESULTS M.ARCH
D	Repeat

NAME: Yat-man (a.k.a. Man)
GROUP: Maintenance
ORIGIN: University of Hong Kong

SPQ PROFILE

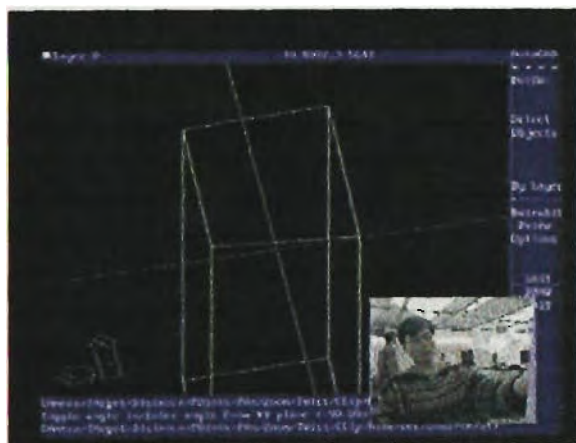


COMMENTS

- - | - 0 | - -

Extreme low scores on surface and achieving and below average on deep motivation. A student having some difficulties relating to learning at this level.

3D EXERCISE



COMPUTING SKILL

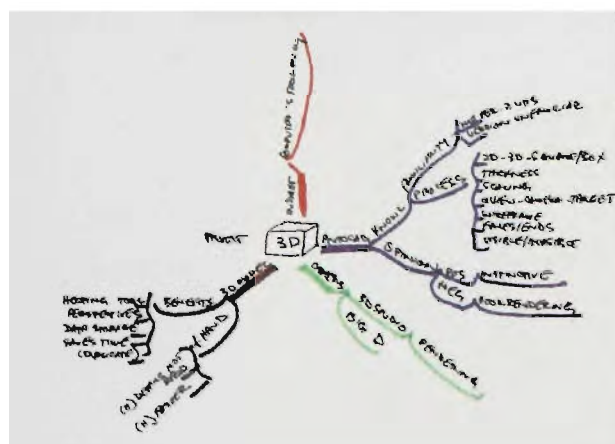
Declarative	Average
--------------------	----------------

Procedural	Average
------------	---------

Contextual Average

Reasonably familiar with AutoCAD.
Was able to draw a basic 3D shape and
managed to open multiview.

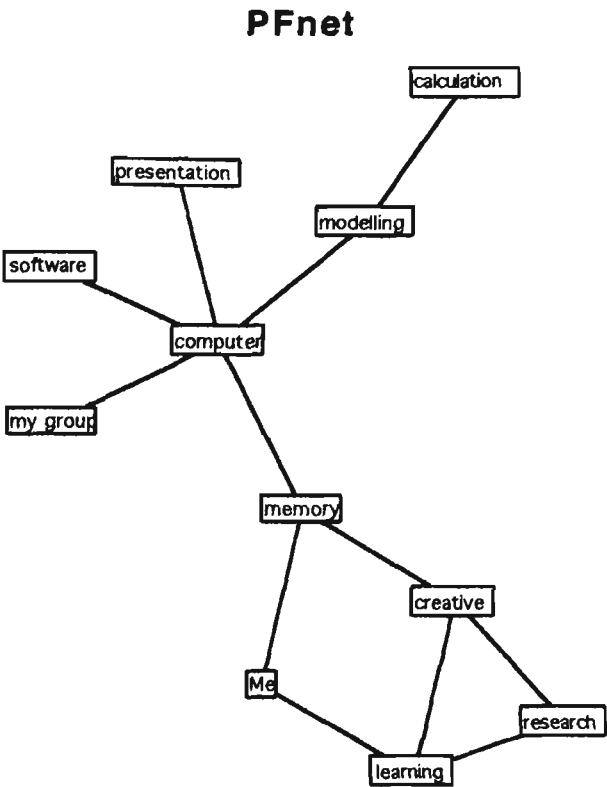
COMPUTING MIND MAP



COMMENTS

Demonstrates familiarity with the process of drawing in AutoCAD, and some contextual knowledge of benefited and comparison with hand drawing. Regards computer as a productivity tool.

PROFILE: Yat-man (cont.)



COMMENTS

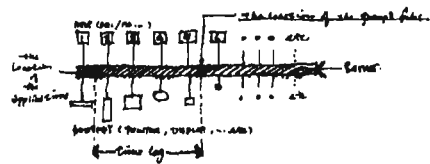
PATTERN: Branching

Yat-man presents a dichotomy between the computer-centred concepts: *group, software, presentation & modelling/ calculation*; and the more “personal” concepts *me, creative, learning & research* — the two groups are linked by *memory*.

Memory obviously has two meanings to Yat-man: on the top it refers to computer RAM; at the bottom it refers to human memory.

Yat-man clearly compartmentalizes computer-related activities (technical) and *learning-creative-research* activities.

MENTAL MODEL OF SERVER



COMMENTS

ACCURACY: 2

SHAPE: Fanciful, Representational

An original, but not very meaningful, attempt to combine the physical lay-out of the network (connections) with the location of the files; as plotted against time.

RESULTS BS1

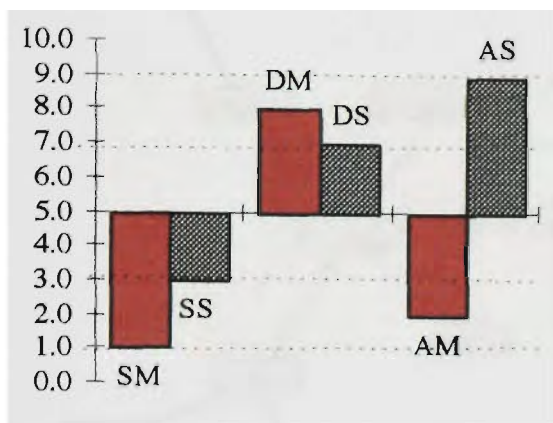
C

RESULTS M.ARCH

C

NAME: Ho-yln (a.k.a. Yln)
GROUP: Temple — Dau-gung
ORIGIN: University of Hong Kong

SPQ PROFILE

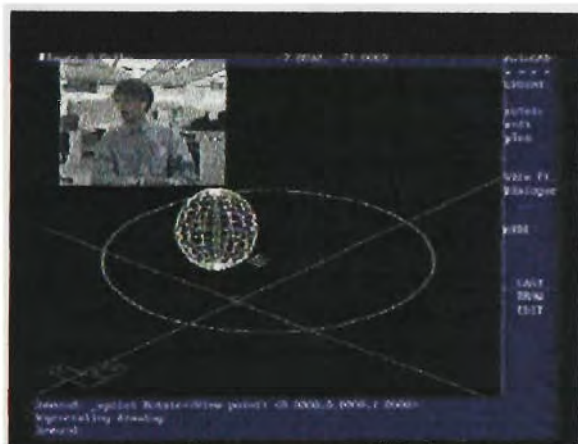


COMMENTS

- 0 + 0 | - +

Committed deep learner with high achieving strategy. Yin is ambitious and intelligent. Low achieving motive but high strategy indicates that he knows how to succeed (though may be unsure of why)

3D EXERCISE



COMPUTING SKILL

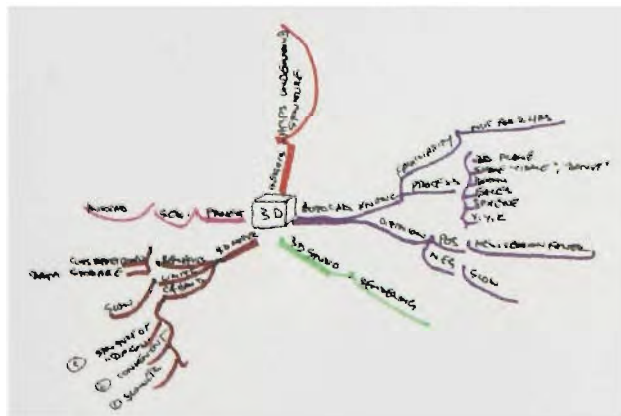
Declarative High

Procedural High

Contextual High

Produced complex, rendered 3D model in AutoCAD

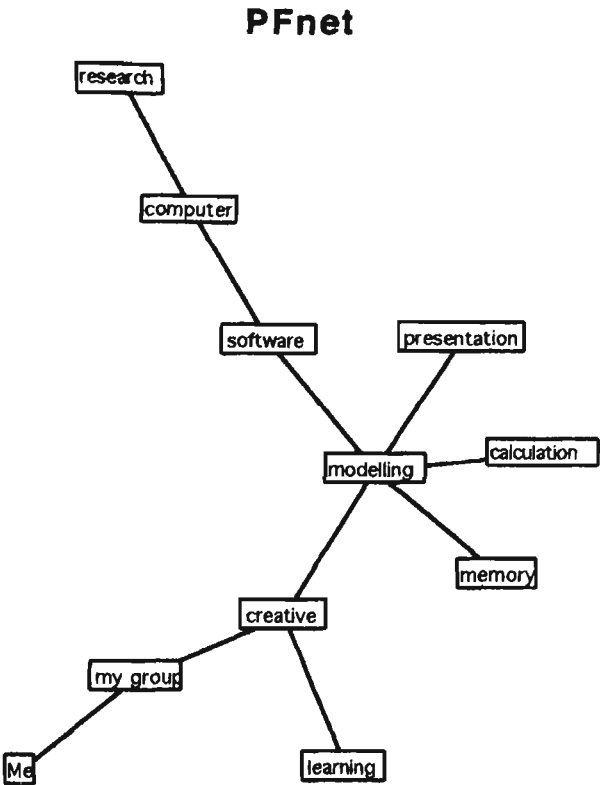
COMPUTING MIND MAP



COMMENTS

Displays high level of procedural knowledge combined with contextual knowledge (benefits, opinions). Says that computer assists him to understand building structures.

PROFILE: Yin (cont.)



COMMENTS

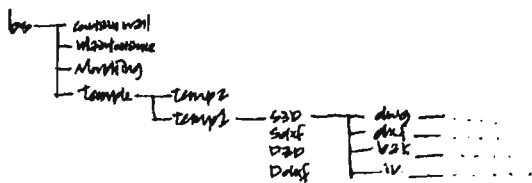
PATTERN: Branching

Yin was one of the team which worked on the *dau-gung* and *modelling* is the concept with the most links — *software*, *presentation*, *calculation*, *memory* & *creative*.

Unlike the other “power” computer users, Yin does not make *computer* the central concept — he seems to regard it more as a tool than as a conceptual anchor.

His net closely resembles the less skilled (but metacognitively aware) computer users — Han, Yat-man, Christina— who make a clear distinction between “technical” and “personal” categories.

MENTAL MODEL OF SERVER



COMMENTS

ACCURACY: 4

SHAPE: Hierarchical, bs

Accurate tree diagram down to the level of individual files.

RESULTS BS1

A

RESULTS M.ARCH

C

Appendix B

OFF-LINE MATERIAL

Computer lab network diagram

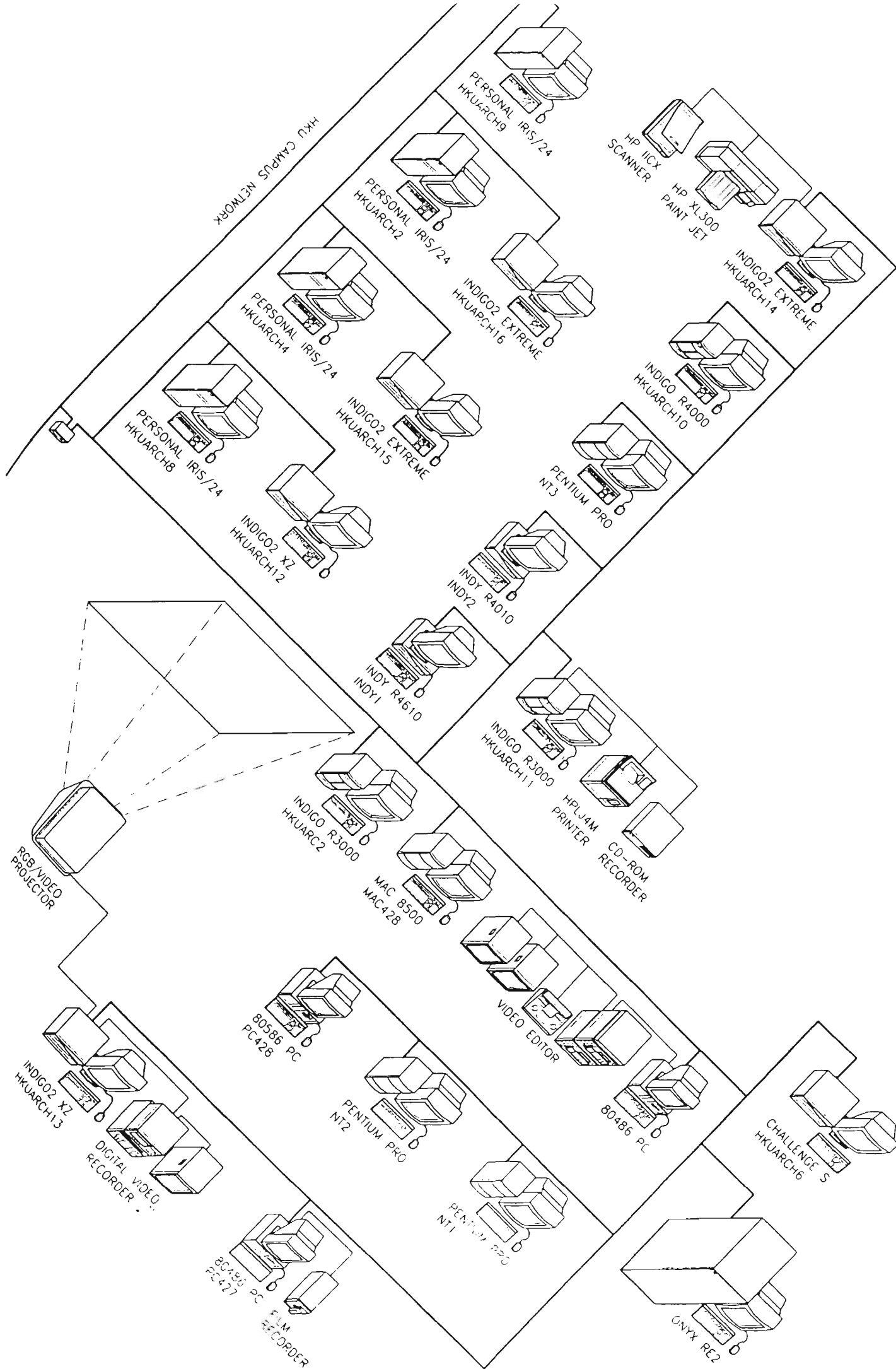
Temple group storyboard

Curtain Wall group schedule

Curtain Wall group storyboard

Maintenance group storyboard

Morphing group storyboard



STORY BOARD

07

INTRODUCTION

ANIMATION

MODEL

CONSTRUCTION

INTRODUCTION PAGE

ANIMATION (3DS INTERIOR ANIMATION, WITH STRUCTURAL DETAILS OF BRACKET SYSTEM)

ROOF

梁架

COLUMN

SCREEN WALL

BASE

BRACKET SYS

IV MODEL

IV MODEL

IV MODEL (SIMPLIFIED DISASSEMBLE)

LINKED TO IV MODEL OF ROOF, 梁架, BASE, SCREEN WALL, ETC)

IV MODEL

IV MODEL

B1

B2

B3

B4

B5

B6

B7

B8

BRACKET COMPONENT

BRACKET

IV MODEL (DISASSEMBLE)

(LINKED TO BRACKET COMPONENT)

CURTAIN = SB2

Please see print copy for images.





BUILDING SYSTEM I – CURTAIN WALL GROUP
PRELIMINARY PROPOSAL M. ARCH 1




CURTAIN1

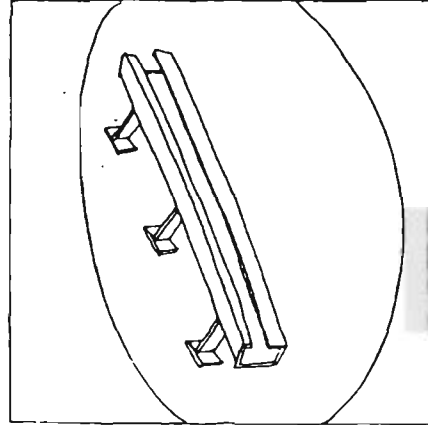
10/02/199

F. CHOI, C. LEE, M. YEN, W. YI

BUILDING SYSTEM
CURTAIN WALL STUDIES

	G.M.S. PRECAST CHANNEL	
	G.M.S. BRACKET	
	G.M.S. SUPPORTING FRAME	
	AL. TRANSOM	
	AL. MULLION	
	AL. HONEYCOMB PANEL	
	AL. PANEL	
	AL. LOUVER	
	ORDINARY GLASS PANEL	
	TEMPERED GLASS PANEL	

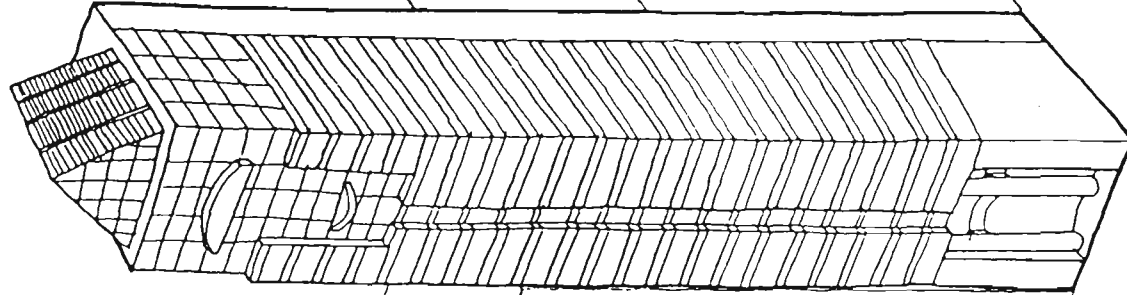
	SILICONE SEALANT	
	STRUCTURAL SEALANT	
	AL. SILL BOARD	
	AL. CORNING	
	AL. HANDRAILING	
	FIBRE GLASS	
	FIRE-STOPPER	
	EXPANSION JOINT	
	FLAGSTAFF	



G.M.S. PRECAST CHANNEL

INSTALLATION
PERIOD
INSTALLATION
PROCEDURE
ADVANTAGE
COST

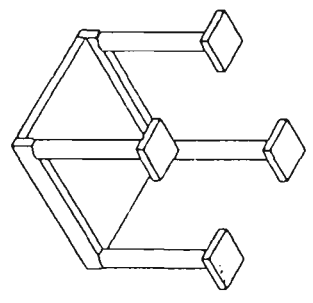
BACK TO
MAIN MENU



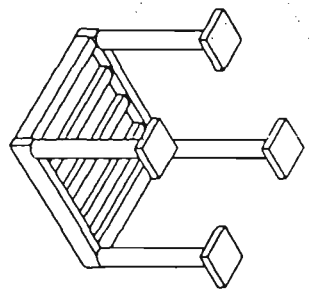
Architect

MORPHING
STRUCTURE

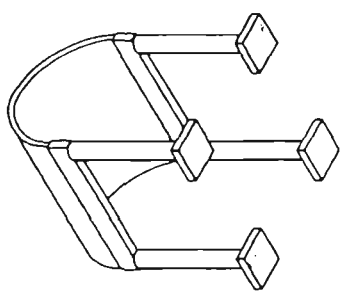
FLAT SLAB



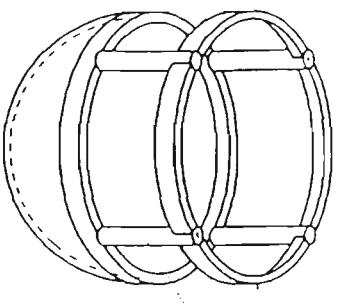
RIB SLAB



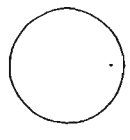
ARCH STRUCTURE WITH COLUMNS



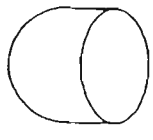
HOLLOW SHELL STRUCTURE WITH COLUMN



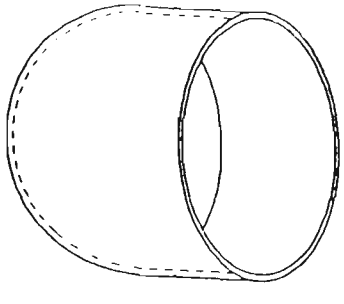
UNSTABLE SOLID SPHERE



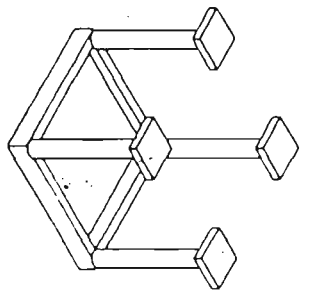
STABLE SOLID



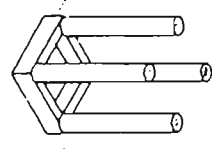
HOLLOW SHELL STRUCTURE WITH SHEAR WALL



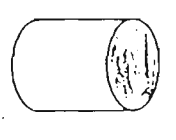
FRAME STRUCTURE



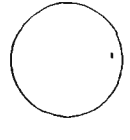
FRAME STRUCTURE



STABLE SOLID



UNSTABLE SOLID SPHERE



Appendix C

REFEREED CONFERENCE PAPERS BASED ON THE WORK IN THIS THESIS

- Bradford, J. W., Hart, I., & Will, B. F. (1995, August). *Cognitive technology in Architecture education*. Paper presented at the First International Cognitive Technology Conference, Hong Kong.
- Hart, I. (1995, December). *Computers as cognitive tools in the teaching of architecture: Evaluation of an action learning project*. Paper presented at the International Conference on Computers in Education, Singapore.
- Hart, I. (1996, June). *Partners in cognition: Problem-based learning with computers*. Paper presented at the Ed-Media 96 - World conference on educational mulimedia and hypermedia, Boston.

COGNITIVE TECHNOLOGY IN ARCHITECTURE EDUCATION

*John Bradford,
Ian Hart,
Barry Will
The University of Hong Kong*

1. Introduction

The teaching of Architecture is a complex process. Its considerable creative demands must be backed by an understanding of science, mathematics and engineering. While most subjects can depend on words to transmit information, the multi-disciplinary nature of architecture demands that students comprehend abstract concepts, processes, visual images and physical objects, which means that educators must augment written and spoken language with images, drawings and 3D models.

In recent times the traditionally generalist nature of Architecture studies has come under pressure as the scope and extent of the separate disciplines of architectural history, structures, services, construction materials and environmental studies have expanded in scale and complexity. Added to this has been the revolutionary impact of computing on all aspects of the architecture discipline.

The project described in this paper represents an attempt to develop a teaching strategy which responds to these changing conditions and explores and tests the potential of high-end workstations as an interactive teaching medium. The authors see it as the precursor of a major change in professional educational methodology for architecture education. (Will, Bradford & Ng, 1993)

2. Educational Context

2.1. A Constructivist learning environment

Brown, Hedberg & Harper (1994) in a discussion of the role of learning theory in the development of computer-assisted learning software state:

Behaviorist and information processing models of learning from the cognitive psychologists focus very closely on task analysis, content and learning outcomes which are identified up front and "contain" or restrict learning experience... (whereas) Constructivists acknowledge that you can set up a learning environment with a content schema and provide the learners with performance support tools to help them integrate and assimilate information, but recognize that the learners must take full responsibility for constructing their own knowledge and understanding. The outcomes are not pre-defined, as the learners' understanding will depend on their prior experience, knowledge and reason for accessing the information. People learn best when they have an immediate need to know something to solve a problem - whether work or study related. (Brown et al, 2)

Jonassen (1991a), in his vision of a constructivist learning environment, described something very close to the system being presented in this paper. He concludes:

Instructional goals and objectives would be negotiated, not imposed... and, if they are used at all, would be a negotiating tool for guiding learners... and for self-evaluation of the learning outcomes. Task and content analysis... would concentrate more on considering appropriate interpretations and providing the intellectual tools that are necessary for helping learners to construct knowledge.

Rather than prescribing instructional treatments, designers would provide generative, mental construction "tool kits" embedded in relevant learning

environments that facilitate knowledge construction by learners Evaluation of learning will become less criterion-referenced... (If we accept that) learners will interpret perspectives differently... evaluation would become less of a reinforcement or control tool and more of a self-analysis tool. (Jonassen, 11-12)

Problem-based learning has been the norm for the studio areas of the architecture program since its inception and there is strong educational justification for the Architecture Department's problem-based, constructivist approach to computer-based teaching, although the decision to introduce it only at the Fourth Year level of the course is influenced by both pragmatic considerations (it is a more expensive mode of teaching than classroom instruction) and the view that the most effective application of constructivist learning environments is at a stage of advanced knowledge acquisition, where learners already have well formed schema and knowledge integration, and where advanced knowledge must be gained in order to solve complex domain- or context-dependent problems.

2.2. Building Systems

The *Building Systems* course is offered in the first year of the Master's degree in Architecture. It is a unit in which students study the various systems which produce the built environment e.g. structure, building skins, air conditioning, plumbing, etc. although comparisons are also made with other systems such as the aerospace, automotive and shipbuilding industries. The course introduces students to advanced and futuristic concepts, while at the same time analyzing traditional methods.

The first semester of the course is taught using a conventional mix of lectures and drawing assignments, with teaching staff taking the lead and establishing the teaching paradigm. Roles are reversed in the second half of the year -- students become the active leaders and staff take the roles of advisors and critics. This section of the course is totally computer-based and is the subject of this paper.

2.2.1. Objectives

From the beginning, the students are made aware of the experimental nature of the course and are involved in decisions about the programme to be followed. The teaching staff define the objectives as follows:

- To make a direct comparison between conventional and computer based teaching methodologies
- To optimize the available time to cover as many aspects of Building Systems as possible
- To increase students' depth of understanding of the systems
- To apportion work to different groups so that parallel programmes can be achieved
- To make a comparison of the difficulties encountered by stand-alone groups compared with groups working on related projects
- To explore the effectiveness of peer teaching and group interaction
- To evaluate the effectiveness of the interactive multimedia, hypermedia, virtual reality and digital virtual design studio (see "3. Computing Environment" below).

2.2.2. Implementation

In the 1994-95 academic year, four projects were put forward for students to work on:

1. An interactive multimedia model of a Tang Dynasty Temple
2. A multimedia presentation of morphing of structure
3. A multimedia presentation of the erection of a curtain wall system for a high-rise building

4. A multimedia presentation of an interactive programme for building maintenance for a high-rise building.

Topics 3 and 4 are directed towards the same building and the two projects are hyper-linked. Data for topics 1, 2 & 3 was supplied by outside sources.

A number of interactive multimedia projects already exist, developed by staff and students in previous years of the Building Systems course. The most complex and complete of these is Temple Tutor -- a set of interactive multimedia models of traditional Chinese temples (Bradford & Will, 1994). Students were introduced to this programme as well as to the various components of the SGI computing environment (described in more detail below).

Students were required to proceed from pen and paper storyboards to 3D computer models produced at the workstations. This was done as group work and has proved to be the most arduous aspect of the course. Each group has encountered different sets of difficulties, ranging from conceptual problems to loss of data and the progress of each project is discussed in weekly presentation sessions with the models presented on a CRT projector for analysis by the entire class.

2.3. Future Developments

As of the time of writing this paper, none of the projects have yet been completed, although a majority of the objectives have been achieved. As with all the previous multimedia work in the Department of Architecture these projects will form the foundation for subsequent student exercises in later years. Additionally, this work will be linked to parallel projects including the Design Information Network Group (DING) -- a joint project with the Chinese University of Hong Kong and the Swire School of Design at the Polytechnic University. We are also using these processes in the Virtual Design Studio (Wojtowicz, 1995) which links Hong Kong with universities in the US, Canada and Spain and we propose to link our multimedia systems with the new Virtual Reality Laboratory.

3. The Computing Environment

3.1. Multimedia & hypermedia

Multimedia deals with the creation, storage and presentation of information in various media forms via computer. Hypermedia provides a hypertext style of interactive access to multimedia information. Existing multimedia and hypermedia systems in education, entertainment and information typically only support text, audio, images and animations and have low screen resolutions, limited display colours and slow graphic processing power. They lack the ability to present the complex line drawings and 3D models which are essential for architectural modelling work. (Bradford, Ng & Will, 1992)

3.2. The Multimedia Lab

The Department of Architecture's Multimedia Laboratory incorporates a network of fast Silicon Graphics workstations together with a variety of input, output and display devices (including video), illustrated in Figure 1.

3.3. Elements:

The system uses digital ASCII text, audio, images, drawings, videos, animations and 3D models, examples of supported formats and software are set out in the table below.

SUPPORTED FILE FORMAT	SAMPLE SOFTWARE
TEXT: ASCII, BIG5 Code	ETEN, MS Word for Chinese Windows
IMAGE: RGB (SGI), TIFF, TARGA, GIF, JPEG	Photoshop, Photostyler, Imageworks
2D DRAWING: IV (Inventor) DXF	AutoCAD
3D MODELS: IV (Inventor) DXF	AutoCAD, 3D Studio

AUDIO: AIFF, AIFC	<i>Sound Editor</i>
ANIMATION: MV (Movie file format), Quicktime, MPEG	<i>Makemovie, Movie Maker, 3D Studio (Keyframer) Wavefront (TAV Advanced Visualizer, Dynamation)</i>

Table 1: File formats & software

3.3.1. *Text, audio & images*

The standard multimedia elements of text, audio and bitmap images are available, and delivery is via a separate X Window viewer for each media type. Figure 2 shows a 3D temple model with a bilingual TextViewer window and the AudioPlayer control panel. Highlighted English words and Chinese characters in the TextViewer indicate hyper-links to additional information about the topic represented by the word or character. Links could be to further text or images, or to a spoken commentary or music presented via the AudioPlayer.

3.3.2. *Drawings*

Any CAL system for architectural education must include provision for drawing. A line drawing may appear to be similar to an image as both are flat 2D graphic elements. The difference is that an image is a bitmap which defines the colours of specific pixels, while a drawing defines vectors which translate into pixels only when the drawing is displayed. This means that drawings can be accurately resized and the individual vectors easily selected as components for hyper-links.

3.3.3. *Movies*

Because all data is digital, computer generated animations and videos are exactly the same and are known as "movies". A movie is a predetermined sequence of images (with or without associated sound track) displayed at a fixed size and a defined frame rate.

3.3.4. *Models*

Architecture students are taught to design 3D objects and spaces which are often too complex to understand when converted to 2D drawings. Current CAD systems can model geometry, light, colour, transparency and texture, but current multimedia systems can't use these models.

The HKU system uses interactive 3D models as another media element, and individual components within the model can be hyper-linked to additional information including other 3D models.

3.4. *Sample session*

A "live" demonstration of these systems will be provided in the conference presentation.

4. *Evaluation*

An undertaking such as this, which sets out to change the way in which Architecture is taught at the University of Hong Kong, is a textbook example of *action research*. The methodology of action research involves a cycle of planning, acting, observing and reflecting -- a sequence which has been followed in this project since its inception. Formal evaluation of the programme has been carried out during the second semester of the 1994-95 academic year with funding from the Action Learning Project.

4.1. *Proposed outcomes*

The evaluation of this project has involved continuous monitoring of the student experience of working within the Multimedia Laboratory environment. The evaluation strategy aims to provide two outcomes:

- Formative evaluation of the software and the learning environment: e.g. its logistical requirements, reliability and effectiveness in achieving its goals. This data is essentially feedback for the programme development team and forms part of the action research cycle.
- Insights into the interaction between student attributes and programme features -- such as 3D modelling -- which can be used to enlighten the process by which the software promotes higher-order thinking: metacognition, schema formation, cognitive complexity, cognitive construction.

4.2. Data collection

The evaluators are collecting the following data:

- **Approaches to learning:** The *Study Process Questionnaire* (Biggs, 1992) is a convenient, easily-administered and widely-accepted instrument which provides standardized norms for Hong Kong university students by institutional type, discipline area and course level. While there are no specific figures for Architecture, there is standardized data for professional courses such as Medicine and Engineering and related disciplines such as Design. The SPQ indicates a student's approach to study -- whether it could be described as *surface*, *deep* or *achieving*, or a combination of these -- and assists the evaluators in assembling a student profile. The test was administered in January, at the beginning of the computer section of the course and re-administered five months later at the conclusion of the course in order to see whether there had been any noticeable changes in attitudes to learning.
- **Conceptual frameworks:** Interviews with participating students to establish their entry-level conception of three dimensional modelling. Using either *AutoCAD* or *3D Studio*, students were invited to demonstrate to the interviewer the underlying concepts and the process of creating a 3D model on a computer. The explanation, and computer output was videotaped and coded using "mind mapping" techniques (see Buzan, 1993). This data, together with the SPQ, provides a "base line" against which to compare later concept formation.
- **Videotaped observations** of student teams as they work on their projects and present their work-in-progress at weekly "crit" sessions with the teachers. The video is coded to provide objective, descriptive information on the process followed by students and their interactions with the software.
- **Videotaped demonstrations/interviews:** Students (individually and in pairs) demonstrate the current progress of their project at key stages throughout the semester. The interviewer also questions them on the dynamics of the group and their particular contributions to the project.
- **Interviews with teachers** (including research assistants and lab technicians) to elicit their views on the learning environment and the progress of the student teams
- **Process documentation** includes notes kept by developers and evaluators, incident reports and minutes of meetings as well as students' preliminary sketches, storyboards, etc..

4.3. *Data reduction & analysis*

Five months of data collection has resulted in more than 150 separate items of data ranging from SPQ score sheets to lengthy open-ended interviews and video tapes. The process of data reduction and indexing is being accomplished using the NUD•IST (Non-numeric Unstructured Data, Indexing, Searching & Theorizing) software developed at LaTrobe University in Melbourne (See Richards & Richards, 1991). We are also experimenting with "mind maps" as a technique for establishing relationships within the data and for illustrating the groups' mental models of their projects.

The NUD•IST tree structure enables the raw data to be indexed at nodes to provide specific information on issues which arose over the course of the semester and then to be searched and cross-indexed to develop and test theories. These issues can be divided into *Product*: formative evaluation of the hardware, software and outcomes of the course; and *Process*: which includes teaching and learning issues.

4.3.1. *Formative Evaluation*

The following are questions which concern the reliability and effectiveness of the software (after Reeves, 1989):

- What are the logistical requirements for implementing the system and what is its reliability with respect to programming, hardware, materials and participation?
- What are student and teacher reactions to the environment?
- What corrections or enhancements need be made to the software and/or the environment?
- What is the perceived effectiveness of the environment with the target group? Does this conform with the measured effectiveness (e.g. from formal assessment)?

4.3.2. *Insights on student learning*

The following are questions concerning the interaction between student attributes and software features (after Tennyson, 1994):

1. Does the use of particular software or working practices improve metacognitive skills and/or domain-specific skills?
2. What metacognitive factors can be identified from the data? e.g.
 - Affective and motivational aspects of thinking (e.g. self-esteem)
 - Cognitive self-appraisal: how do students act on what they say is important (e.g. declarative, procedural, contextual knowledge)?
 - Cognitive self-management: what students say they will do and their subsequent actions -- e.g. their plans, strategies and performance monitoring (evaluating, planning, regulating)
 - Self-regulation: continuous metacognitive adjustments in response to feedback (from their teachers and peers, and from the software)
 - Self-knowledge: of strengths and weaknesses, comparison with others
 - Task knowledge: of the types of cognitive tasks required to undertake the project
3. Were there observable differences in methods of work and level of achievement between students with high and low scores on deep/surface learning or intrinsic/extrinsic motivation (as measured on SPQ)? Were there observable/measurable changes in attitude or motivation in the course of the study (e.g. from the SPQ retest, from interviews)?

4. What new schemas or conceptual frameworks were developed by students in the course of the semester? What evidence could be observed for development of cognitive complexity and/or cognitive construction?

4.4. Theorizing

At the time of submitting this paper (May, 1995) a number of wider issues have begun to arise from the evaluation, which may become the main focus of discussion by the time of the conference presentation.

4.4.1. Distributed cognitions

The question of the impact of so-called intelligent technologies on human thinking and learning has been the subject of increasing debate since the early 80s (Papert, 1980, 1987; Pea, 1987; Salomon, 1993). *Intelligent technology* does not necessarily mean *artificial intelligence*. The simple hand-held calculator, as well as sophisticated programs like AutoCAD and 3D Studio, undertake significant cognitive processing on behalf of the user and thus become partners in what Pea (1987) calls "distributed intelligence". The interrelationship between the individual, the group and the computer is an issue which has drawn a great deal of comment in both the student interviews and the observations of the teaching staff.

4.4.2. Cognitive tools vs. performance support software

At what stage does performance support software become a *cognitive tool*? There is a difference between using the computer to increase efficiency (e.g. by designing one floor of a curtain wall skyscraper and pushing the "Duplicate" button for the other 39 floors) and accepting the computer as partner in creativity. For some students the transition is easy and natural, but some may never take this step.

4.4.3. Normative issues

There are concerns about deskilling: just as the typewriter made copperplate irrelevant and the electronic calculator undermined the teaching of multiplication, so there are fears that computer could undermine skills in drawing and design. Many students stressed their preference for working with pencil and paper and preferred to regard the computer purely as a device to present their ideas to clients or as a convenient means of electronic information storage; although paradoxically, none of their projects could have been accomplished without a computer.

4.4.4. Effects with and of computers

The question of whether a computer technology can have any effect on students' intellectual performance has been reframed by Salomon and others (Salomon, Perkins & Globerson, 1991; Salomon, 1993) to challenge our notions about human ability. They differentiate between effects *with* and effects *of* computer tools: "... working *with* an intelligent tool has effects on *what* students do, *how* well they do it, and *when* it is done", whereas effects *of* the technology refers to perceived "changes in mastery of knowledge, skill or depth of understanding once the student is away from the computer." (Salomon, 1993, 3) Although it may be true that the software in the Multimedia Lab totally redefines the tasks of conceptualising, drawing and presenting information, it is yet to be demonstrated that they also leave any cognitive residue in the form of improved ability to conceptualise a form or a space, or to communicate this information in their absence. "One can plan, design... experiment, and simulate in ways not possible until now. But does this partnership make students any smarter, better skilled communicators, or better skilled learners (or, alternatively, less skilled) as a result?" (Ibid)

4.4.5. *Practical issues*

Technology, modes of activity, cognitive affects and culturally prescribed functions for that technology are interrelated. As Simon (1987) has observed: if you *have* a technology you are likely to use it. However,

...no important impact can be expected when the same old activity is carried out with a technology that (simply) makes it a bit faster or easier; the activity itself has to change, and such a change cannot take place in a cultural vacuum... But this means that it is not the technology alone affecting minds but the whole 'cloud of correlated variables' -- technology, activity, goal setting, teachers' role, culture -- exerting their combined effect. Consequently, to engineer a desirable effect either with or of an intelligent technology requires a lot more than just the introduction of a new program or tool. (Simon, 1987, 8)

The practical advantages of this mode of teaching have been demonstrated in the impressive results which students have achieved in their projects. But for the Department of Architecture's considerable investment in computing facilities to have a long-term impact on the curriculum and style of teaching, let alone the mode of operation in the architecture profession, these and related issues will need to be researched further and debated more widely.

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Computers as cognitive tools in the teaching of architecture: evaluation of an action learning project.

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ABSTRACT

The paper sets out the framework for the evaluation of a problem-based, constructivist learning environment employing computers as learning support tools in Architecture. The style of the evaluation is ethnographic rather than positivist; qualitative rather than quantitative; hypothesis generating rather than hypothesis testing. The data collection and analysis is structured with the aid of the NUD•IST (Non-numerical Unstructured Data; Indexing, Searching & Theorising) software package. As the paper has been written at the mid-point of the evaluation process it does not present conclusions but speculates on the types of issues which are arising from the study: the stage at which learning support software becomes a true cognitive tool; the possible nature of distributed cognitions in computer-based group project work; normative issues in the use of computers in design; theoretical issues such as the effect of computers on students' intellectual performance; and practical issues such as the way projects such as this affect the nature of university teaching.

1. Learning support software

A computer-based Learning Support Software (LSS) system for the teaching of undergraduate Architecture is under development at the University of Hong Kong as part of an ongoing program of research and development. The project aims to explore the effectiveness of state-of-the-art technology such as interactive multimedia, hypermedia, virtual reality and digital video conferencing to improve the quality of professional education. The first elements of the system are now being utilised within the undergraduate program as an Action Learning Project.

The Evaluation component of the Action Learning Project, supported by University Grants Commission central funding, aims to investigate the effectiveness of a constructivist learning environment in the teaching of Architecture at the University of Hong Kong

The original rationale for the development of the system was based on the following assumptions (see Will):

- students will need to learn to use a wide range of computer software for future employment
- the use of interactive multimedia will promote engagement and creativity in students working in a problem-based learning environment
- three dimensional (3D) computer modelling is a cost- and time-effective means of demonstrating and testing architectural problems
- an open-ended, hypermedia system can promote the integration of a number of strands of the Architecture syllabus presently taught as separate units, e.g. Design, History, Structures, Building Materials, Environmental Controls.

1.1. Context & content

The software system is currently being employed within the context of a problem-based learning unit on Building Systems, at fourth year level in the Architecture degree. Most of the students (average age 24) have completed three years of the undergraduate course and have had one year of professional placement in an

architectural firm; some students are graduates from other institutions and are taking the unit as part of a Masters program.

The suite of inter-linked software runs in a laboratory of networked Silicon Graphics computers. The software comprises both *content schema* (data base) and *performance support tools* (authoring software). (See Bradford)

1.1.1. **Content schema**

This material has been developed by students in previous years and is the basis of a dynamic and evolving collection of hyper-linked data. It currently consists of:

- *Temple Tutor*, a data base of four traditional Chinese temples modelled from measured drawings, which can be manipulated and disassembled in 3D and investigated from numerous aspects: historical, physical properties, design, structural detail, etc.
- *Hypermedia Dictionary* of architectural terms, materials, structures, etc. related to the data base -- by selecting a section of the 3D model the Dictionary can be invoked to provide information on it and further hypertext links within the dictionary encourage open-ended exploration. The Dictionary is constantly evolving as an ongoing student project in another Unit.

1.1.2. **Performance support tools**

The following file formats and software are supported by the system

SUPPORTED FILE FORMAT	SAMPLE SOFTWARE
TEXT: ASCII, BIG5 Code	ETEN, MS Word for Chinese Windows
IMAGE: RGB (SGI), TIFF, TARGA, GIF, JPEG	Photoshop, Photostyler, Imageworks
2D DRAWING: IV (Inventor) DXF	AutoCAD
3D MODELS: IV (Inventor) DXF	AutoCAD, 3D Studio
AUDIO: AIFF, AIFC	Sound Editor
ANIMATION: MV (Movie file format), Quicktime, MPEG	Makemovie, Movie Maker, 3D Studio (Keyframer) Wavefront (TAV Advanced Visualizer, Dynamation)

1.2. **Project goals**

The Action Learning project has the following aims:

- to actively engage students through the possibility of dynamic representation of buildings and structures in three dimensions
- to provide opportunities for experimentation, modelling, testing and evaluation in project work
- to develop metacognitive skills such as self-appraisal and self-management, particularly in regard to problem-solving
- to encourage "deep" approaches to learning (Marton & Säljö, 1976; Biggs, 1992) by promoting the integration of different aspects of the syllabus e.g. history, materials, structures, design, construction.

1.3. **Student projects**

The following projects have already been carried out or are currently underway with fourth-year students using this system:

- a model for rainfall and drainage patterns with different roof designs (1994);
- animated models of the effects of lateral and vertical stress on building structure (1994);
- a morphing sequence to illustrate historical development of roof construction from pillars supporting flat roof, through arches and vaults to domes;
- plans for a Buddhist religious complex using traditional designs and materials;
- a systems model for the construction of curtain-walled buildings.
- a hyper-linked maintenance matrix for curtain-walled buildings

2. Constructivist learning environments

Brown, Hedberg & Harper (1994) in a discussion of the role of learning theory in the development of computer-assisted learning software state:

Behaviorist and information processing models of learning from the cognitive psychologists focus very closely on task analysis, content and learning outcomes which are identified up front and "contain" or restrict learning experience... (whereas)... Constructivists acknowledge that you can set up a learning environment with a content schema and provide the learners with performance support tools to help them integrate and assimilate information, but recognise that the learners must take full responsibility for constructing their own knowledge and understanding. The outcomes are not pre-defined, as the learners' understanding will depend on their prior experience, knowledge and reason for accessing the information. People learn best when they have an immediate need to know something to solve a problem - whether work or study related. (p.2)

Laurillard (1993) puts the case for *situated cognition* in university teaching, as in life, arguing that learning at all levels is more effective when it takes place in the context of realistic problems and that context becomes an important component of the knowledge base which students acquire.

Because academics are concerned with how their subject is known, as well as what is known, teaching must not simply impart decontextualised knowledge, but must emulate the success of everyday learning by contextualising, situating knowledge in real-world activity... (thus) academic learning must be situated in the domain of the objective, the activities must match that domain; and academic teaching must address both the direct experience of the world, and the reflection on that experience that will produce the intended way of representing it. (Laurillard, 1993, 29)

The idea of a constructivist, problem-based learning environment is not new. It dates back at least as far as John Dewey (1938), although the greatest impetus in recent times has come from the work of Papert (1980) which has been developed over the past decade by IT writers such as, Brown, Collins & Duguid (1989), the Cognition & Technology Group at Vanderbilt (1990), Harel & Papert (1991), Jonassen (1991a) and Hannafin (1992). In his vision of an ideal constructivist learning environment, Jonassen concludes:

Instructional goals and objectives would be negotiated, not imposed... and, if they are used at all, would be a negotiating tool for guiding learners... and for self-evaluation of the learning outcomes.

Task and content analysis... would concentrate more on considering appropriate interpretations and providing the intellectual tools that are necessary for helping learners to construct knowledge

Rather than prescribing instructional treatments, designers would provide generative, mental construction "tool kits" embedded in relevant learning environments that facilitate knowledge construction by learners

Evaluation of learning will become less criterion-referenced... (If we accept that) learners will interpret perspectives differently... evaluation would become less of a reinforcement or control tool and more of a self-analysis tool. (Jonassen, 1991a, 11-12)

There is, therefore, strong support from current Instructional Technology research for the Architecture Department's approach to teaching, although the decision to introduce it only at the Fourth Year level is influenced by both pragmatic considerations (it is a more expensive mode of teaching than classroom instruction) and a view that the most effective application of constructivist learning environments is at a stage of advanced knowledge acquisition, where learners already have well formed schema and knowledge integration, and where advanced knowledge must be gained in order to solve complex domain- or context-dependent problems.

3. Evaluation

Evaluation is an integral part of the cycle of any Action Learning project: both evaluation of the materials and environment, and evaluation of the quality of learning which is taking place. In Jonassen's view, evaluation of constructivist learning most appropriately emphasises higher-order thinking -- it focuses on the *process* within an authentic task rather than on the *product* of the task. "The evaluation should be context driven and dependent, accepting the likelihood of multiple perspectives, the possibility of a range of tasks, and the need to be evaluated by a panel of goal-free examiners from a range of backgrounds". (Jonassen, 1991b, 31)

This evaluation strategy of this Action Learning Project aims to provide both product and process outcomes:

- *Product:* Formative evaluation of the software and the learning environment: e.g. its logistical requirements, reliability and effectiveness in achieving its goals. This data is essentially feedback for the program development team and forms part of the action research cycle; and

- *Process*: Insights into the interaction between student attributes and program features -- such as 3D modelling -- which can be used to enlighten the *process* by which the software promotes higher-order thinking: metacognition, schema formation, cognitive complexity, cognitive construction.

3.1. Data collection

The primary emphasis of this evaluation is on *process*, and the style is exploratory rather than experimental. The desired outcome is not the proof or disproof of a hypothesis; it is more likely to be open-ended -- a set of phenomenographic categories or issues which require further investigation. The students are not manipulated as dependent variables but included as active participants in the process. The style of data gathering is therefore, ethnographic rather than positivist; primarily qualitative rather than quantitative; hypothesis generating rather than hypothesis testing.

Qualitative research typically produces records which are rich and complex, but difficult to analyse rigorously. Focus for the organisation of this project is provided by the NUD•IST computer package -- software originally designed to aid researchers in the Social Sciences to manage large amounts of Non-numeric Unstructured Data. It does his by supporting processes of Indexing, Searching and Theorising (Richards, 1993).

A characteristic of qualitative research is that it is dynamic. As the data collection process proceeds the researcher is required to develop ideas and categories for thinking about the records, linking them and exploring the links within the data. This, in turn, affects the ways in which future data is collected and categorised. NUD•IST facilitates this process through its "tree" structure which enables the data to be indexed in a flexible and dynamic fashion; and it encourages exploration and searching of the indexing nodes according to the developing theories of the researcher (Richards & Richards, 1991). The computer package is, in effect, a cognitive tool of the researchers -- a framework for conceptualising and managing the Action Learning Project itself.

3.1.1. Non-numeric, unstructured data...

At the time of writing, the following seven types of data are being collected by the evaluators:

- 1 **Approaches to learning:** The *Study Process Questionnaire* (Biggs, 1992) provides information on a student's approach to study -- rating it on scales for *surface*, *deep* or *achieving*, or a combination of these -- and assists the evaluators in assembling a student profile. It is a convenient, easily-administered and widely-accepted instrument which provides standardised norms for Hong Kong university students by institutional type, discipline area and course level. While there are no specific figures for Architecture, there is standardised data for professional courses such as Medicine and Engineering and related disciplines such as Design. The Questionnaire is administered at the beginning of the course and at the end, to establish whether any changes in attitudes to study can be measured.
- 2 **Conceptual frameworks:** Interviews were conducted with participating students to establish their entry-level conception of three dimensional modelling. Using either *AutoCAD* or *3D Studio*, students were invited to explain to the interviewer the underlying concepts and the process of creating a 3D model. The explanation, and computer output was videotaped and coded and "mind maps" (Buzan, 1993) were constructed to help provide a phenomenographic description of students' concept formation.

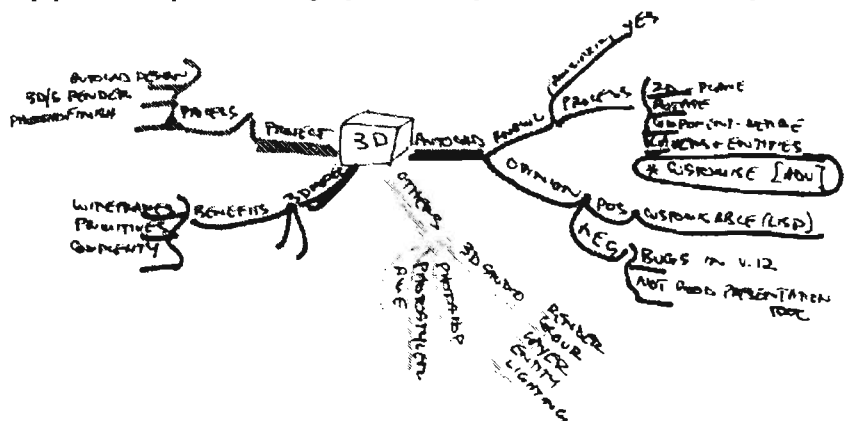


Fig 1: "Mind map" of student interview on 3D modelling

3. **Videotaped observations** of student teams as they work on their projects and present their work-in-progress at weekly "crit" sessions with the teachers and in the final session on which they are assessed. The video data is coded to provide objective, descriptive information on the processes followed by students and their interactions with the software.
4. **Videotaped demonstration/ interviews:** Students (individually and in pairs) demonstrate their project to the interviewer at key stages throughout the term and discuss the progress of the exercise. The interviewer also questions them on the dynamics of the group, their particular contributions to the project and their individual learning styles. This material is also coded and transcribed for indexing under NUD•IST.
5. **Interviews with teachers** -- including research assistants and lab technicians -- to provide their assessments of the learning environment and the progress of student teams.
6. **Process documentation** includes diaries kept by developers and evaluators, incident reports, minutes of meetings, notes, as well as students' preliminary sketches, storyboards, etc..

3.2. Indexing

The NUD•IST tree structure enables the data to be indexed at nodes to provide specific information on issues which arise over the course of the evaluation. These issues can be divided into *Product*: formative evaluation of the hardware, software and outcomes of the course; and *Process*: which looks at teaching & learning issues.

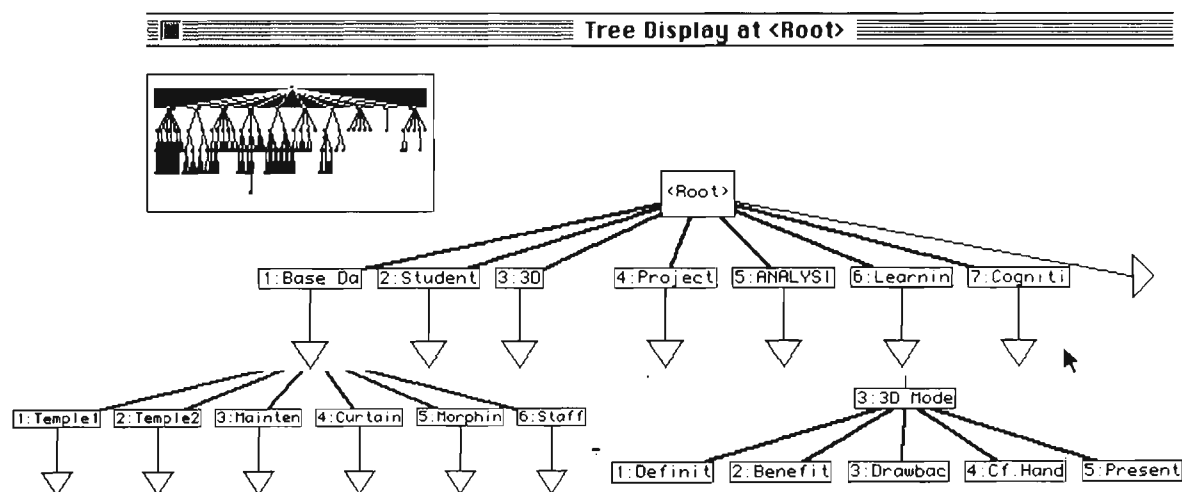


Fig 2: Tree display from NUD•IST

3.2.1. Formative Evaluation

The following are questions which concern the reliability and effectiveness of the software (after Reeves, 1989):

- a. What are the logistical requirements for implementing the LSS and what is its reliability with respect to programming, hardware, materials and participation?
- b. Does this environment appear to be more effective with individual students or with small groups?
- c. What are student and teacher reactions to the LSS environment?
- d. What corrections or enhancements need be made to the software and/or the environment?
- e. What is the perceived effectiveness of the environment with the target group? Does this conform with the measured effectiveness (e.g. from formal assessment)?

3.2.2. Teaching & learning issues

The following are questions concerning the interaction between student attributes and features of the learning environment:

1. Does the use of particular learning support software improve metacognitive skills and/or domain-specific skills?
2. What metacognitive factors can be identified from the data (SPQ, observation, interviews)? e.g.
 - Affective and motivational aspects of thinking (e.g. from SPQ)

- Cognitive self-appraisal: how do students act on what they say is important (e.g. declarative, procedural, contextual knowledge)?
 - Cognitive self-management: what students say they will do and their subsequent actions -- e.g. their plans, strategies and performance monitoring (evaluating, planning, regulating)
 - Self-regulation: continuous metacognitive adjustments in response to feedback (from their teachers and peers, and from the software)
 - Self-knowledge: of strengths and weaknesses, comparison with others
 - Task knowledge: of the types of cognitive tasks required to undertake the project
3. Were there observable differences in methods of work and level of achievement between students with high and low scores on deep/surface learning or intrinsic/extrinsic motivation (as measured on SPQ)? Were there observable/measurable changes in attitude or motivation in the course of the study (e.g. from the SPQ retest, from interviews)?
 4. What new schemas or conceptual frameworks were developed by students in the course of using the LSS? What evidence could be observed for development of cognitive complexity and/or cognitive construction? (Tennyson, 1994, provides a model for linking cognitive complexity and cognitive construction with what he terms "computer-based prescriptions")
 5. Was cognitive transfer observed in the course of using the software -- includes both "low road" (transfer of detail and low-level knowledge) or "high road" (transfer of relational, conceptual knowledge)? (Salomon, 1991)
 6. Specific questions on the ways in which students relate to 3D modelling tools such as *AutoCAD* & *3D Studio*:
 - a. are there particular schemata and conceptual frameworks which depend on a "deep" understanding of 3D modelling?
 - b. how does the ability to use 3D representation assist students to develop new schemata and conceptual frameworks?
 - c. can we observe instances of transfer and/or cognitive construction which stem from the employment of 3D modelling techniques in either representation or authoring?

3.3. Searching & Theory building

Once the data is in and the process of indexing has begun, NUD•IST provides sophisticated means of searching and theory-building. The following are some of the issues which are arising at the mid-point of the investigation (July 1995). Following the "grounded theory" approach, future interviews and observations will be slanted towards investigating these questions more thoroughly:

3.3.1. Learning support software vs. Cognitive tools

When does a performance support software, such as AutoCAD or 3D Studio become a cognitive tool? There is a difference between using the computer to increase efficiency (e.g. by designing one floor of a curtain wall skyscraper and using the "Duplicate" menu for the other 30 floors) and accepting the computer as partner in creativity. For some students the transition is easy and natural; we suspect that some will never make the final step. We began the study by testing the students with Biggs' *Study Process Questionnaire* (which provides scores on Deep/Surface/Achieving approaches to learning) and we propose to compare the results with student attitudes to computing at the beginning and end of the course.

3.3.2. Distributed cognitions

The question of the impact of so-called intelligent technologies on human thinking and learning has been the subject of increasing debate since the early 80s (Papert, 1980, 1987; Pea, 1987; Salomon, 1993). *Intelligent technology* does not necessarily mean *artificial intelligence*. The simple hand-held calculator, as well as sophisticated programs like AutoCAD and 3D Studio, undertake significant cognitive processing on behalf of the user and thus become partners in what Pea (1987) calls "distributed intelligence". The interrelationship between the individual, the group and the computer is closely linked to peer teaching (a stated objective of this course) and is an issue which has drawn a great deal of comment in both the student interviews and the observations of the teaching staff.

3.3.3. Normative issues

There are concerns about deskilling: the typewriter was the death of copperplate; the calculator made multiplication tables unnecessary; will the computer subsume the skills of drawing and design? These views are expressed by members of the Architecture teaching staff. The students also voice these concerns and -- at least at the beginning -- many said they preferred to work with pencil and paper and saw the computer purely as a presentation device. But it is interesting to note that none of the current projects could have been accomplished without a computer: the Buddhist nunnery project is only made possible by the Department's data base of CAD drawings of traditional temples; the curtain wall and maintenance models aim to produce a computer data base; and morphing is an exclusively computer form.

3.3.4. Effects *with* and *of* computers

The question of whether a computer technology can have any effect on students' intellectual performance has been reframed by Salomon and others (Salomon, Perkins & Globerson, 1991; Salomon, 1993) to challenge our notions about human ability. They differentiate between effects *with* and effects *of* computer tools: "... working *with* an intelligent tool has effects on *what* students do, *how* well they do it, and *when* it is done", whereas effects *of* the technology refers to perceived "changes in mastery of knowledge, skill or depth of understanding once the student is away from the computer." (Salomon, 1993, 3) Although it may be true that the software in the Multimedia Lab totally redefines the tasks of conceptualising, drawing and presenting information, it is yet to be demonstrated that they also leave any cognitive residue in the form of improved ability to conceptualise a form or a space, or to communicate this information in their absence. "One can plan, design... experiment, and simulate in ways not possible until now. But does this partnership make students any smarter, better skilled communicators, or better skilled learners (or, alternatively, less skilled) as a result?" (Ibid)

3.3.5. Practical issues

Technology, modes of activity, cognitive effects and culturally prescribed functions for that technology are reciprocally interrelated. As Simon (1987) has observed, if you have a technology, you are likely to use it. However,

...no important impact can be expected when the same old activity is carried out with a technology that makes it a bit faster or easier; the activity itself has to change, and such a change cannot take place in a cultural vacuum... But this means that it is not the technology alone affecting minds but the whole 'cloud of correlated variables' -- technology, activity, goal setting, teachers' role, culture -- exerting their combined effect. Consequently, to engineer a desirable effect either with or of an intelligent technology requires a lot more than just the introduction of a new program or tool." (Salomon, 1991, 8)

The Department of Architecture's considerable investment of both money and effort in developing this form of teaching is likely to have a long-term impact on the style of teaching Architecture and related subjects at the University of Hong Kong. In the longer term it may even affect the way in which the Architecture profession operates.

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Partners in Cognition: Problem-Based Learning With Computers.

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It is now generally accepted that learning is a constructivist process in which students are actively involved in the creation of knowledge by restructuring their existing mental schemata in the light of new information. At university level, there is a great deal of interest in the creation of educational environments to support constructivist learning. Many of these environments include computers.

The subject of the study is a one-year unit in the post-graduate Architecture program at the University of Hong Kong, in which students worked in small groups in a computer laboratory to produce interactive three-dimensional models of building systems. The projects involved real-world problems such as a maintenance model for a Hong Kong curtain-walled building, an educational VR model of a Tang Dynasty temple and a morphing system to illustrate the historical development of roofing structures.

Using predominantly qualitative research methods, we set out to ask the question: "In a problem-based, constructivist learning environment, what is the relationship between student characteristics, computers and cognition?" The tools included videotaped talk-aloud protocols, cognitive mapping with Pathfinder networks and the Study Process Questionnaire. Analysis was carried out using the NUD•IST software. Four interlinked issues have emerged which appear to be central to successful "cognitive construction" in this type of environment.

- **Approach to learning:** a "deep" approach to learning — as measured by Biggs' (1992) Study Process Questionnaire — was a characteristic of students who had successful strategies for working with computers;
- **Acquiring structural knowledge:** while declarative and procedural knowledge of both architectural and computing domains was a stated objective of the course, structural knowledge emerged as the core issue in successful completion of the projects;
- **Metacognitive awareness:** for efficient functioning of the group it was essential that students were aware of their own and other's strengths and weaknesses in both declarative knowledge and procedural skills and had definable strategies for acquiring new knowledge and skills;
- **Distributed cognitions:** sharing of knowledge and skills was a characteristic of this working environment, so much so that it appeared to be the only feasible way of approaching the task; the most successful project groups accepted the computer as a "partner" in distributed cognition.

By the end of the exercise, many students were conscious of the computer having affected the ways in which they approach a task and go about achieving it. Salomon (1993,3) differentiates between the effects with and effects of computer tools: "... working with an intelligent tool has effects on what students do, how well they do it and when it is done", whereas effects of the technology refers to perceived "changes in mastery of knowledge, skill or depth of understanding once the student is away from the computer." (Salomon, 1993,3)

This paper represents work in progress, to aim of which is to establish whether the experience of working with computers leaves any cognitive residue in the form of improved ability to conceptualize a form or a space, or to communicate this information in the absence of the computer.

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