The effectiveness of computer assisted learning in construction

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THE EFFECTIVENESS OF COMPUTER ASSISTED LEARNING IN CONSTRUCTION

by

Vian Shawket Ahmed

A Doctoral Thesis submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of Loughborough University

February 2000

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SYNOPSIS

It is widely recognised that learning and training is a life long task and that people may need to be retrained or acquire new skills several times during their working careers. This poses the problem of what are the most appropriate teaching methods available to match the wide range of experience and learning styles of the learners. The development and implementation of new technology for teaching and learning purposes is one of the solutions to these problems.

In construction the need for continuous learning is evidenced by the CPD (Continuing Professional Development) requirements of all the major professional institutions. One method which appears to have great potential, is Computer Aided Learning (CAL). CAL can be defined as, a way of presenting educational material to a learner by means of a computer program which gives opportunity for individual interaction.

Several initiatives have been launched over the last few years, to both develop and explore the use of CAL in higher education. Unfortunately few of these initiatives introduced strategic approaches for implementing these tools, which are aimed at the needs and styles of users within the construction domain. Also, only 'qualitative' rather than 'quantitative' measures of the effectiveness of these tools are provided, if any.

Against this background, this research project:

- reviewed literature outlining learning theories that are relevant to learning in construction;
- reviewed the preferred learning styles of different professional groups within the construction domain;
- reviewed literature of the role of CAL in higher education, and the different types available in construction.

As a result of the above literature reviews, the research has:
• developed an understanding of the learning process and derived measures of effective learning according to the cognitive, experiential and behavioural learning theories;
• categorised the different styles of CAL and their role in supporting the learning process, and promoting different types of learning;
• proposed a framework for strategic planning, development, implementation and evaluation of CAL, and highlighted how such tasks are a shared responsibility between the educator, the developer and the users of CAL;
• tested the effectiveness of a CAL system, the MERIT2 simulation game, adopting the evaluation criteria introduced by the proposed framework, and using quantitative measures of the efficiency and effectiveness of this tool to promote learning in construction management;
• adopted the approach introduced by the proposed framework, for strategic implementation of a prototype multimedia CAL tool, to meet the educational needs and learning styles of undergraduate quantity surveying students.

The thesis concluded that, qualitative measures are insufficient to determine the effectiveness and efficiency of CAL tools. Also, that these tools are effective methods to support teaching within the construction domain, when strategically developed and implemented to target the educational needs and learning styles of its users.
ACKNOWLEDGEMENT

This thesis was made possible through the support of many people. I particularly thank my supervisor and mentor Professor Tony Thorpe, for his support and excellent guidance during the time taken to produce this thesis. I equally thank Mr. Willy Sher, my second supervisor, and Professor Ronald McCaffer my director of research for their encouragement and support.

Acknowledgement to all my friends and to members of staff in the Department of Civil and Building Engineering at Loughborough University, for making my research days pleasant and memorable.

Finally, I am most thankful to my mother and all members of my family for their love, care and encouragement across the miles.
To Heveine

My sweet heart & source to my inspirations

‘ Thanks for putting up with mummy all these years ’
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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE RESEARCH

The construction industry has a continuous demand for engineers with a high level of cognitive and experiential skills. This is due to the dynamic, varied and competitive nature of this industry. These skills have traditionally been built up over many years including university/college courses and on the job training. It is now widely recognised that learning and training is a life long task and that people may need to be retrained, or acquire new skills several times during their working careers. This is evidenced by the CPD (Continuing Professional Development) requirements of all the major institutions.

Engineering education needs to undergo dramatic changes in order to keep up with a changing industry and society. This leaves educators with a challenge of preparing engineering students for the industry, and giving them enough background and incentive to pursue graduate studies. Therefore it is necessary to define measures that will contribute to engineering education. Jaraiedi and Ritz (1994) and Back and Sanders (1998) argue teaching “learning” is part of these measures.

Research on educational psychology, shows that people differ in their ways of thinking and learning. Also, different domains acquire learners with certain learning strategies that match that domain. Such strategies can either be developed or shaped. Failure to recognise these strategies may result in failure in the learning process. For example, experiential learning (i.e., learning by doing) is the norm for learning in engineering. However, the nature and complexity of the construction industry makes learning by doing, a risky, time consuming and costly task. It requires learners to be actively involved in real construction tasks.

One method which appears to have great potential to promote the required learning strategies in construction is Computer Aided Learning (CAL). CAL can be defined as,
a way of presenting educational material to a learner by means of a computer program which gives the opportunity for individual interaction (Davies and Crowther, 1995). Within the last five years, the availability of computer hardware and software have enabled the wide spread development of CAL tools. This has been encouraged by several national initiatives, launched to both develop and explore the use of CAL, such as the Teaching and Learning Technology Programme (TLTP), and Teaching with Independent Learning Technologies (TILT). These efforts have resulted in the availability of CAL tools for educational purposes within different domains particularly in higher education. These tools promote different learning skills in Engineering and other disciplines, but unfortunately few of these have addressed learning in construction. The full potential of these tools, particularly within the construction domain, is yet to be explored and developed. Such potential lies in the capabilities of CAL tools to simulate the real life situations of different construction tasks, and to promote effective learning within a safe environment, hence, producing individuals who will meet the demands of the construction industry.

CAL options recommended by Higher Education need an appreciation of the context and requirements that will ensure effective implementation. This is supported by the Dearing report (1997), stating that 'There is less satisfaction with Computer Assisted Learning packages than the traditional modes of teaching and learning' and that 'despite the potential of Computers and the new technology, and some major initiatives, there is yet little widespread use of computer-based materials'. Thus, to explore the potential of CAL within the construction domain, these questions must first be answered: What are the measures of the effectiveness of CAL? and how can these tools be developed and implemented to meet the needs of the construction domain?

Previous research by Tam and Cham (1995), Lansely, (1982), AbouRizk (1993), The Teaching and Learning Technology Programme 'TLTP' (1996), and Tonks and Armitage (1997) shows that measures to evaluate the effectiveness of CAL tools within the construction domain are qualitative rather than quantitative, and often lack evidence to whether the learners’ educational needs and learning strategies are met. Such measures can be misleading and are risky both financially and educationally.
because the time and resources spent to develop these tools may be time wasted in learning. Therefore, the judgements made by the TQA (Total Quality Assessment) schemes to monitor the quality of teaching in higher education, must be influenced by evidence of the evaluation and proof of the effectiveness of such tools, rather than the implementation of new technology as a new trend within the curricula (Roffe, 1998). Thus there is a need for deriving measures of the effective development and implementation of CAL within construction curricula, and to propose new approaches that can assist educators revise their educational targets (Quayle and Murphy, 1999). Sloan (1996) states ‘..... The task of the educator is to provide environmental opportunities which are sufficiently challenging for learners, without being so difficult as to de-motivate them.’ and ‘to support this, educators must attempt to match the learning experience to the level of ‘maturity’ of the individual student (i.e. the learning experience should, where possible, be tailored to the specific needs of the student)’. This suggests that, it is only through developing a clear understanding of learners’ needs, that an effective learning situation through the use of CAL can take place. This highlights the importance of educational psychology in recognising how individuals learn, which becomes the driving measures for effective CAL.

Research undertaken by Lowe (1992), Kolb (1984) and Skitmore (1989), showed that learners within the construction domain not only differ in their learning styles from learners in other domains, but also between different professional groups. One rare example of CAL tools addressing students’ learning styles, was presented by Powell (1993). Powell developed four versions of CAL courseware for Architectural students to match four learning styles. Powell’s work proved successful in promoting effective learning for each category of learner. This indicates that this is an important and relevant area not only for the developers of such systems, but also for the people for whom the systems are designed. The effectiveness of CAL is therefore a mechanism which combines functionality and performance in addressing needs and learning tasks. The main focus of this research is to study the use of CAL within the construction domain, and to propose strategic approaches for the development and implementation of these tools. The study has been undertaken through the development of a framework for strategic implementation of CAL, based on an understanding of learning theory and the processes of learning. The implementation of these strategies
resulted in introducing quantitative as well as qualitative measures of CAL tools. The wide use of ‘Computer Based Simulation Games’ in construction management, and the qualitative measures of their effectiveness, led to evaluation of the ‘MERIT2’ construction management simulation game, applying quantitative measures to investigate its effectiveness.

This research also explores the potential use of various types of CAL for different professional groups in construction and reports on its use in this field. However, despite the need and the potential use of CAL tools to support the learning of building elements and the principles of quantity surveying measurement rules, this research has revealed a lack of CAL tools to support learning in quantity surveying measurement. According to Lowe (1992), the learning strategies in this field require the ability to visualise the components of a construction process and how such components are combined to form a whole. This is a difficulty that is often faced by students with little or no previous construction experience. This prompted the development of a prototype multimedia exercise, to promote student’s learning in this subject area. A strategic approach for planning, developing and evaluating this work was adopted, using the proposed framework.

1.2 RESEARCH HYPOTHESES

The hypotheses of this research are that,

i. qualitative measures are insufficient on their own as measures of the effectiveness of CAL

ii. CAL is an effective educational tool within the construction domain, when tailored to learners’ specific needs and learning styles.

These hypotheses will be tested through the aims and objectives of this research.

1.3 THE AIMS AND OBJECTIVES OF THE RESEARCH

The aim of this research is to review, develop and test measures of effective learning using CAL within the construction domain.
This aim is divided into the following objectives:

1. To develop an understanding of the learning process from literature, identify learning theories that are relevant to learning in construction, and derive indicators of effective learning in relation to this field.

2. To identify indicators of effective learning through the use of CAL.

3. To propose a strategic framework for defining the different stages for developing, implementing and evaluating CAL tools effectively.

4. To use the evaluation criteria proposed within the strategic framework, to test hypothesis (i) above. This is to be undertaken applying quantitative approaches for evaluating the effectiveness of an existing CAL tool used in construction education.

5. To identify the need for different CAL tools within the construction domain, and adopt a strategic approach using the framework in (3) to develop a CAL tool to test its effectiveness, to verify hypothesis (ii).

The main emphasis of this research is to relate indicators of effective learning and individuals’ learning strategies to the development and implementation of CAL in construction. To build or strengthen such strategies, learners’ needs and learning styles and, the role of CAL in promoting these needs and styles are addressed.

1.4 RESEARCH APPROACH

To meet the research objectives, the following research tasks were undertaken:

1. A comprehensive literature survey was undertaken to:
   • develop an understanding of the learning process, and identify learning theories that are relevant to learning in construction;
   • highlight evidence of individuals learning styles within the construction domain;
   • identify indicators of effective learning from learning theory;
• identify types of CAL and their capabilities in promoting the required skills and strategies in construction.

2. A framework for strategic planning, implementation and evaluation of CAL tools was developed based on the derived measures of effective learning from literature.

3. A detailed study of computer based simulation games was undertaken surveying their applications and use, their role in promoting the learning process, and evidence of their effectiveness as CAL tools. This resulted in a case study developing quantitative measures of the effectiveness of the MERIT2 Construction Management simulation game, guided by the evaluation criteria proposed by the framework in (2). This study included a pilot survey to trace 600 previous MERIT2 participants, who used MERIT2 to enhance their Continuous Professional Development. A sample of Post graduate students taking part in MERIT2 as part of their programme was also surveyed.

4. A study of multimedia tools as an example of CAL was undertaken, identifying their functionality, capabilities, limitations, and their role in promoting the learning process. In this study, multimedia was seen as convenient mechanism to aid existing educational difficulties and needs faced in teaching ‘Quantity Surveying Measurements’ for undergraduate students. Therefore a multimedia exercise was developed targeting these needs. To aid this investigation, students’ learning styles were surveyed and number of different media (text, images, animation and video clips) were compiled, targeting the imagery styles of novice quantity surveyors.

1.5 ACHIEVEMENTS OF THE RESEARCH
The research set out to investigate measures of the effectiveness of CAL tools within the construction domain, and how such measures can lead to strategic development and implementation and evaluation of these tools. The main achievements of the research are summarised below:
1. The learning processes and learning strategies of graduates, required to meet the needs and demands of the construction industry, were identified.

2. Identification of methods used to underpin individuals’ learning styles, and how these styles can be stimulated or shaped when appropriate methods of teaching are applied.

3. Categorisation of different types of CAL tools, and how these tools assist in developing different skills and learning strategies.

4. The identification of simulation and gaming as CAL tools that match the learning styles of novice civil engineers. Also, the recognition of Multimedia CAL tools to match the learning styles of novice quantity surveyors.

5. The development of a generic framework for strategic development, implementation and evaluation of CAL tools.

6. Introducing a quantitative approach for evaluating the MERIT2 simulation game as a training tool in the construction industry and as an educational tool to support the learning process in higher education. This approach can be adopted and widely used to evaluate other computerised simulation games.

7. The identification of core problems faced in teaching and learning quantity surveying in the undergraduate domain.

8. The strategic approach to the development, implementation and evaluation of a prototype multimedia tool, targeted at the teaching and learning needs and requirements for understanding principles of the quantity surveying measurement rules.

The identification of learning strategies and learning skills required by the construction industry is a key factor in producing successful engineers. The identification of available CAL tools and how they simulate the process of learning is an important
factor in deciding the most suitable CAL tool to simulate defined learning skills or
stages of the learning process. By the development of a framework for creating
strategic CAL tools, the important role of the educator, developer and users are better
defined, together with their paths of communication during the different stages of any
CAL project. The evaluation of the MERIT2 simulation game introduces a new
approach that can be adopted for evaluating other similar CAL tools. Similarly, the
development, implementation and evaluation of a multimedia CAL exercise to meet the
learning styles of novice quantity surveyors, demonstrates the value of the strategic
framework in developing effective CAL tools.

1.6 A GUIDE TO THE THESIS
The thesis consist of three parts which are divided into eight chapters. A schematic
guide to the thesis is illustrated in Figure 1.1. A brief summary of each chapter is
presented below:

PART I INTRODUCTION

Chapter 1 Introduction
This chapter explains the background to the research, the research hypothesis, the aims
and objectives of the research. The work undertaken to achieve the objectives, main
achievements and the guide to the research are also presented.

PART II LITERATURE REVIEW AND CURRENT PRACTICE

Chapter 2 Learning theory and measures of effective learning
This chapter reviews the relevant literature describing the learning process, types of
learning defined by different learning theories, individuals' learning styles, deep and
surface approaches to learning and previous work undertaken by researchers in
relation to learning and learning styles in construction. Existing measures of effective
learning are also highlighted and presented in relation to the construction domain.
Chapter 3 Effective learning and the use of CAL
This chapter reviews the history and background to the development and use computer based media to date, classifies their types and reviews their existing application in higher education and construction. Measures of effective learning derived from learning theory are used for proposing a framework for strategic planning, development, implementation and evaluation of CAL tools. The chapter concludes with the research hypothesis.

Chapter 4 Simulation and gaming
This chapter defines simulation games, reviews their history and background to date, their existing applications within the construction domain and describes their role in promoting the experiential learning process. Literature surveyed in this chapter also identifies simulation games as tools to promote the convergent learning styles of novice civil engineers. This chapter studies the MERIT2 simulation game in details and proposes a quantitative rather than qualitative approach to investigate its effectiveness, adopting the strategic approach proposed by the framework developed in Chapter 3.

Chapter 6 Multimedia in construction
This chapter develops a definition of multimedia CAL tools from literature, identifies their capabilities, limitations and applications in higher education and construction and their types and role in promoting the learning process in construction. The study in this chapter supports the second hypothesis of the research, and describes the QSMM exercise (Quantity Surveying Measurement in Multimedia), which was strategically developed to cater for the educational difficulties faced in teaching measurement rules to first year undergraduate students, adopting the strategic framework proposed in chapter 3.

PART III EXPERIMENTAL WORK

Chapter 5 Evaluation of MERIT2
This chapter investigates the effectiveness of the MERIT2 simulation game, by applying quantitative measures proposed in Chapter 4, and undertaking a pilot survey.
tracing 600 previous participants working in industry, and surveying sample participants in their post graduate courses. Quantitative analysis are carried out using computerised statistical packages. The results of these surveys are presented in this chapter.

**Chapter 7 QSMM: Quantity Surveying measurements in multimedia**
This chapter adopts the strategic approach proposed by the framework developed in Chapter 3, to evaluate the effectiveness of QSMM by surveying samples of QSMM users. The outcomes of these surveys are presented in this chapter.

**Chapter 8 Conclusions and recommendations**
This chapter discusses the research findings, conclusions and limitations of the research, and proposes recommendation for further research.
Part I: Introduction

Introduction (Chapter 1)
This chapter gives background to the research, its hypothesis, aims and objectives and the research approach. Achievements of the research are also includes & a guide to the thesis.

Learning theory & measures of effective learning (Chapter 2)
This chapter investigates different definition of learning and reviews learning theories that are related to learning within the construction domain. Learning styles defined by different theorists are also reviewed. This chapter concludes measures of effective learning and learners' learning style in construction. Some of the hypothesis are included in this chapter.

Effective learning and the use of CAL (Chapter 3)
This chapter defines CAL and identifies the different styles. The chapter also describes how learning with CAL is influenced by learning theory and the different types of learning it could promote. Measures of effective learning through CAL are derived and summarised in a strategic framework concluding hypothesis.

Part II: Literature review & current practice

Hypothesis

Simulation Games (Chapter 4)
This chapter defines Simulation Games and reviews their existing applications in construction with the main focus on MERIT2 simulation.

Multimedia in construction (Chapter 6)
This chapter includes:
Definition of multimedia
Their capabilities and limitations
Application in higher education
Multimedia & in construction

Evaluation of MERIT2 (Chapter 5)
This chapter surveys two samples of MERIT2 participants to investigate its effectiveness. The results of this survey are also included.

Evaluation of QSMM (Chapter 7)
This chapter describes the strategic approach adopted to develop QSMM and its the evaluation process.

Part III: Examples of CAL & experimental work

Conclusions and Recommendations (Chapter 8)
Conclusions and limitations of the research
Recommendations for further research.

Figure 1.1 Guide to the research
CHAPTER TWO

LEARNING THEORY AND MEASURES OF EFFECTIVE LEARNING

2.1 INTRODUCTION

2.2 LEARNING THEORIES (TYPES AND ORIGIN)

2.3 DEFINITIONS OF LEARNING
   2.3.1 The experiential learning theory
   2.3.2 The cognitive learning theory
   2.3.3 Conditioning or Behavioural Theory

2.4 LEARNING STYLES
   2.4.1 Experiential Learning Styles
   2.4.2 Cognitive Learning Styles

2.5 EFFECTIVE APPROACHES TO LEARNING

2.6 SUMMARY
CHAPTER 2

LEARNING THEORY AND MEASURES OF EFFECTIVE LEARNING

2.1 INTRODUCTION

The underlying assumption of this research is that the highly competitive construction industry demands individuals that are educated and trained, with a high level of experiential and intellectual skills. This creates continuous pressures on curricula developers to introduce new methods of learning to meet these demands. However, with the increasing use of computers and new technologies, there is a risk of this technology being used inappropriately rather than as a tool that targets the educational aims and objectives. This results in wasted resources and learning opportunities. To prevent such losses, educators need to understand the learning strategies that can be developed through the use of these tools. This study suggests that, by understanding the learning process and measures of effective learning, effective development and implementation of educational tools can occur, hence minimising the risks.

The main focus of this chapter is to derive measures of effective learning that can be incorporated within the study of the effectiveness of CAL tools in construction, proposed in Chapter 3. To assist with this enquiry, the main aims of this chapter are to:

- develop an understanding of the concept of learning and the learning process, defined by different theorists;
- review methods of identifying individuals' learning styles;
- highlight the use of learning theory in relation to the construction discipline by other researchers, and
- identify approaches that lead to effective learning, and the development of effective methods of learning.

The following section provides a review of the types and origin of learning theories to help define the concept of learning, as this underpins the future work of this study.
2.2 LEARNING THEORIES (TYPES AND ORIGIN)

Since the seventeenth century, systematic theories of learning have emerged to challenge existing theories. These theories may be classified into two broad families, namely, S-R (stimulus-response) conditioning theories of the behaviourist family and cognitive theories of the Gestalt-field family.

For behaviourists or conditioning theorists, learning is a change in behaviour. It occurs through stimuli and responses becoming related according to mechanistic principles. Thus, it involves the formation of relations of some sort between series of stimuli and responses. Stimuli (the causes of learning) are environmental agents that act upon an organism so as either to cause it to respond or to increase the probability of a response of a certain class or kind. Responses (effects) are physical reactions of an organisation to either external or internal stimulation (Bigge and Shermis, 1992). For Gestalt theorists, learning is a process of gaining or changing insights, outlooks, or thought patterns. These theories prefer the terms “persons” to “organism”, psychological environment to physical or biological environment, and interaction to either action or reaction. These terms are highly advantageous for educators in describing learning processes. They enable the educator to see the persons, their environment, and their interaction with their environment all occurring at once (Bigge and Shermis, 1992).

To summarise the difference between the two families, S-R conditioning theories interpret learning in terms of changes in strength of hypothetical variables called S-R connections, associations, habit strengths, or behavioural tendencies; Gestalt-field theorists define learning in terms of reorganisation of perceptual or cognitive fields or systems. Consequently, a behaviourist educator desires to change the behaviours of his/her students in a significant way, while a Gestalt-field oriented educator aspires to help students change their understandings of significant problems and situations (Bigge and Shermis, 1992, Cotton, 1995). It is within the interest of this research to study theories that are derived from both families. However, the domain of learning is so large that there are not just different schools of theories, but different theories within these broad schools (Claxton, 1990). According to Mumford (1993), different theories deal with different aspects of learning, varying in value, depending on the individuals'
learning needs and the stages of their development. Orta (1999) argued that 'there exists as wide a cleavage as there ever was between educational theory and practice ... educators labour at length on the importance of individual differences in theory, but teach the same material to individuals regardless of their abilities in practice'. Therefore, to identify the appropriate theories which will inform this study, the following section reviews the definitions of learning given by a number of the principal theorists.

2.3 DEFINITIONS OF LEARNING

A number of definitions of the concept of 'learning' have arisen from different schools of thought. Although these definitions vary in description, they agree in principle. For example, according to Mumford (1980), the behaviourist view of learning in its simplest terms is defined as a relatively lasting change in performance where, '... learners know something they did not know earlier, and can show that they know it. learners are able to do something they were not able to do before'. While the definition of learning presented by the views of cognitive theorist is described as '...a cognitive activity that involves the use of intellect for the development and structuring of understanding about oneself and the world in which one lives. Learning is a continuous process of organising and reorganising what is known and believed to be true on the basis of new evidence. This process occurs within the individual, and during this process numerous personal and emotional attributes interact. Additionally, theorists agree that learning culminates in change' (Wilson, 1980, Kolb, and Robin et al, 1990).

Smith (1983), reflects the view of the experiential theorists and states; '... when learning is used to describe a product, the emphasis is on the outcomes of the experience ... When learning is used to describe a process, an attempt is made to account for what happens when a learning experience takes place ... When learning is used to describe a function, the emphasis is on certain important aspects (like motivation), which are believed to help produce learning ...'.

Theorists also agree that, learning is a change that can result when ... [people] interact with information [materials, activities, experience]. It occurs to the extent that learners are motivated to change, and it is applied in the real world to the extent that they take
successful steps to integrate the learning into the real world situation (McLagan, 1978, Smith, 1983, Reed, 1996). This definition addresses learning as a ‘change’ that results from ‘experience’. According to Aminmansour (1994), ‘experience’ is a key factor to learning in construction and is difficult to identify. It requires an understanding of the learning process, and how the information gained from experience is processed in the mind. Therefore, the following need to be examined:

- experiential learning theory, to develop an understanding of how learning from experience occurs;
- cognitive learning theory, to develop an understanding of how the information received, from experience, is processed and developed into cognitive and intellectual strategies;
- behavioural learning theory, to derive measures of changes in behaviour as a result of the learning process.

The rest of this section provides a review of these theories, which will help identify the factors which influence the effective use of Computer Assisted Learning tools as a source of experience to facilitate experiential learning in construction. This will also help identify the stages of learning that can be simulated by various types of Computer Assisted Learning tools, and to develop evaluation criteria to assess the learning outcomes of these tools.

2.3.1 The experiential learning theory

The experiential learning theory offers the foundation for an approach to education and learning as a life long process. This can be observed from Kolb’s experiential learning model (Kolb, 1984), which pursues a frame for examining and strengthening the critical linkages among education, work, and personal development as shown in Figure 21. Such linkage is of great relevance to the needs of the highly competitive construction industry, which requires individuals with excellent experiential and intellectual skills, and continuous personal and professional development (Moore and Exley, 1995). This highlights the importance of understanding the experiential learning process and the development of learning strategies related to this domain. However, to develop such an understanding, the following terms must first be defined:
i. Experience

The term ‘Experience’ has been defined as the “actual observation of, or practical acquaintance with facts or events, practise in doing something or knowledge or skill gained from this experience or meet with, feel, find by, undergo or suffer ” (Oxford dictionary, 1996).

ii. Types of experience

The number of types of learning identified and described in various publications is extensive. Their names and definitions depend heavily on the author and on the perspective of analysis. Psychologists however, have widely accepted that the process and content involved in learning vs. learning for improvement may not be the same (Barnett, 1994). While the first might be the cognitive process of initial learning, the second concept requires particular mechanisms and techniques which might help an individual to improve his/her effective performance. This research needs to address both types of learning in relation to learning in construction. The first type of learning concerns novice individuals with no previous construction experience. Whilst the second type concerns individuals who have some experience but need learning for improvement. Mumford (1989) demonstrated some examples that emphasise the range of learning opportunities which are capable of facilitating both type of learning. These include:

(a) On the job learning
- unplanned learning through the current job,
- planned, created learning within current job responsibilities,
- planned learning through additions to current responsibilities,
- planned learning through special assignments,
- planned learning by experience outside work,
- planned learning from superiors or colleagues.

(b) Off the job learning
- courses, seminars, conference and workshops,
- reading.
voluntary work.
(Mumford, 1980, 1989 and 1993)

‘On the job’ learning provides a learning opportunity that can be supported by implementing CAL tools, to facilitate construction processes within a classroom environment. ‘On the job learning’ is also described by Kolb and Rubin et al (1990) as learning from the direct experience, which can be simulated through ‘interactive learning’. Section 3.3, describes in details how CAL tools can be disseminated to support this type of learning effectively.

iii. Experiential learning

The original definition of learning mentioned earlier in this section, reveals two aspects of experience; the actual participation in an ‘activity’, and ‘the knowledge or learning derived from it’. Such engagement in an activity is addressed by the experiential school of thought as “experiential learning”. According to Claxton (1988) “experiential learning is about building up a vast and accurate repertoire that enables individuals to get to where they want to be from where they find themselves, as reliably as painlessly as possible. Thus experiential knowledge binds inseparably together ‘what one can do’ with specifications of ‘when to do it’ and ‘what to do it for’”. Although these theories agree in principle, the terms used in describing each stage of the “experiential learning process” differ.

For example, Figure 2.2 presents the experiential learning process introduced by Honey and Mumford (1989), which involves four mutually dependent stages, doing something - experiencing, thinking about what happened - reviewing, drawing some conclusions - concluding and deciding what to do in a similar situation - planning. While, Kolb’s experiential learning theory, describes the experiential learning process as being a cycle which can be conceived in four-stages: concrete experience, observation and reflection, formation of abstract concepts and generalisation and
Figure 2.1 Experiential learning as the process that links education, work and personal development (source, Kolb 1984)

Figure 2.2 Honey and Mumford's learning cycle (source, Honey and Mumford 1989)
testing implications of concepts in new situations, as shown in Figure 2.3. One of the most relevant features of this theory is that the direction the learning takes is governed by learners needs and goals. Learners seek experiences that are related to their goals, interpret them in the light of their goals, and form concepts and test implications of these concepts that are relevant to these felt needs and goals. The implication of this fact is that the process of learning is erratic and inefficient when personal objectives are not clear (see section 3.3.1-i). Habeshaw (1990), adopted Kolb’s theory and produced a list of tools that support the different stages of the learning process described by Kolb. Habeshaw addressed simulation games and the use of computers as a source of experience as shown in Figure 2.4.

Binsted (1980), developed a model of experiential learning that involves three integrated processes: reception of input, discovery, and reflection. These occur within the learner (inner world) or as a result of external stimuli from the outer world (see Figure 2.5). According to Binsted, this is a process whereby learners fit new ideas or concepts into their existing cognitive maps. Binsted maintained that “the most complete and satisfactory learning occurs when all three learning stages are present and are linked together in continuous cycles of learning”. This theory models the learning process through the use of simulation games as described in section 4.2. According to Dennison and Kirk (1990), “learning occurs as a result of doing mainly because we can observe other changes in behaviour and attitudes and identify greater knowledge (in ourselves and others) following experience”. These examples suggest that the cyclic nature of the experiential learning process is continuously recurring, i.e., concepts are continuously tested in experience, and modified as a result of observation of that experience. This theory is of particular relevance to the development of educational media, and the continuous testing of the learning outcomes, which will help improve the experiences introduced in the first place.

iv. Reflection

One of the key elements in learning from experience is reflection. This is clearly observed from the theories of Kolb, Honey and Mumford, Binsted and Dennison and

iv. Reflection
One of the key elements in learning from experience is reflection. This is clearly observed from the theories of Kolb, Honey and Mumford, Binsted and Dennison and
Concrete experience

Testing implications of concepts in new situations

Formation of abstract concepts and generalisations

Observation and reflections

Figure 2.3 Kolb's Experiential Learning Process (source Kolb, 1984)

Figure 2.4 Experiential Learning - Experience as a source of learning and development (source Habeshaw, 1990)
Kirk, addressed in section 2.3.1-iii. Therefore an individual’s experience needs to be followed by some organised reflection, as stressed by Boud and Keogh et al (1985). Boud and Keogh et al also support the notion that, learning can be enhanced by learners attending to ways in which they can focus attention on events and extract meaning from their experiences through a variety of reflective activities. Clift and Houston et al (1990) stated that “the skill of experiential learning in which people tend to be most deficient is reflection”. According to Boud and Keogh et al (1985), reflection is needed at various points: at the start in anticipation of the experience; during the experience as a way of dealing with the vast array of inputs and coping with the feelings that are generated; and following the experience during consolidation. Boud and Keogh et al also stressed that, “Reflection is an important human activity in which people recapture their experience, think about it, mull it over and evaluate it. It is this working with experience that is important in learning. The capacity to reflect is developed to different stages in different people and it may be this ability which characterises those who learn effectively from experience... While reflection is in itself an experience it is not, of course, an end in itself. It has the objective of making us ready for new experience. The outcome of reflection may include a new way of doing something, the clarification of an issue, the development of a skill or resolution of a problem”. This is illustrated in a model produced to represent the reflection process in context (see Figure 2.6).

Reflection not only enables the individual to learn from the experience, but also helps identify any need for some specific learning before further experience is acquired. This is supported by a model developed by the Further Education Unit (1978), suggesting that the learning process should be considered as being in three phases, and is illustrated by the representation of an expanding triangle, composed of experience, reflection and specific learning (see Figure 2.7).

Therefore, reflection is of importance for:

- educators who need to implement evaluation methods which will enable them (students) to reflect upon the lessons learnt at different stages of the learning process as a result of implementing CAL tools, and help modify these tools in view
Figure 2.5 Whole cycle learning model (source, Binsted 1980)

Figure 2.6 The reflection process in context (source Boud, Keogh et al 1985)
Experience

existing and as extended by company, college or other agency

Preparatory to more

Giving material for Etc.

Reflection

Indicating need for

Specific Learning

usually of skills and knowledge and varying from individual to individual

Reflection

guided by tutor, usually serving to consolidate interpret and pattern develop concepts and theories; perceive attitudes and values; as well as......

Figure 2.7 F.E.U. Experiential learning model (source F.E.U. 1978)
of the targeted aims and objectives;

- learners who are involved in a learning situation, reflecting upon the knowledge gained at different stages of the learning process; and
- the ‘CAL’ developers, who seek to develop effective CAL tools, which will enable learners to reflect upon the knowledge gained and develop their learning strategies.

These features are discussed further in chapter 3.

The main principles of the experiential learning theory and the different stages it involves, provide a guide to establishing the principles of effective development and evaluation of Computer Assisted Learning tools, and will be referred to later on in this research. The abilities generated from the different stages of learning through this process are referred to in section 2.4.1 of this chapter.

2.3.2 The cognitive learning theory

According to the cognitive theorists, learning, is an interactive process within which a person attains new insights or cognitive structures or changes old ones (Bigge and Shermis 1992). This is important to this research in developing effective teaching and learning strategies. This theory, describes how the information gained (whether from direct experience or interpretation of acquired experience), is processed in the mind of the individuals to develop their intellectual skills.

i. The cognitive learning process

The Piagetian theory describes the development of cognitive processes in childhood as the key to understanding the nature of human knowledge itself and that intelligence is shaped by experience. Piaget addressed intelligence of the individual as a product of the interaction between the person and his or her environment. In Piaget’s terms, the key to learning lies in the mutual interaction of the process of assimilation (the tendency to distort or alter our encounters with new objects and experiences so that they fit within our existing understanding, i.e. our cognitive structure) and the process of accommodation (the tendency to alter our cognitive structures to fit the objects we encounter). Learning, or in Piaget’s terms intelligent adaptation, results from a balanced tension between these two processes (Piaget, 1961).
Paiget's work identifies four major stages of cognitive development as illustrated in Figure 2.8 and listed below.

(a) **The sensory-motive stage;** where learning is predominantly inactive through feeling. The environment plays a major role in shaping the ideas and intentions. Learning occurs primarily through the association between stimulus and response (section 2.3.2 - ii).

(b) **Representational stage;** at this stage, the concrete orientation is retained and the development of a reflective orientation begins to internalise action, converting them to images. Learning is predominately iconic in nature, through the manipulation of observation and images.

(c) **Concrete operation;** Learning at this stage relies on the concepts and theories to select and give shape to the experience gained.

(d) **Formal operation;** this stage returns to a more active orientation that is modified by the development of the reflective and abstract power that preceded it. The learners at this stage develop the possible implications of their theories and proceed to experimentally test which of these are true (Piaget, 1961).

Piaget's work was parallel to Bruner (1966), who saw in the growing of knowledge of cognitive developmental processes the scientific foundations for a theory of instruction. Knowledge of cognitive developmental stages would make it possible to design curricula in any field in such a way that subject matter could be taught to learners at any age or stage of cognitive development.

Handy (1993), also gave an explanation of learning which basically illustrates the cognitive approach, emphasising internal mental processes. This approach considers the four stages that the processes of learning comprises:

(a) **Exploration.** This is when the individual asks himself: 'Is there a problem?' 'What do I need to know in order to be able to deal with it?' When the problem is internalised (i.e., understood and accepted through the thinking process), real learning follows.

(b) **Conceptualisation.** The nature of the problem having once been explored, the individual must conceptualise it, and learn how to set this one experience of the
problem in a more general context or framework. If the individual does this, he/she will be able not only to explain the first problem but all others like it. Without concepts the isolated experience becomes mere anecdote, an experience talked of but not learnt from. Only if the next experience is precisely the same as the preceding one can the lessons of the first be applied to the second.

**c. Experimentation.** It is this action consequent on conceptualisation that is here called experimentation. These acts of experimentation test out the conceptualisation and, if successful, implant the concepts more firmly in one's mind. If we do not experiment with the concepts they remain remote theory.

**d. Consolidation.** This is the final stage. Concepts are internalised and begin to mesh in one's mind. The experimental phase is past, and the new hypothesis becomes the basis for future action. The concept ceases to be tentative, and habitual behaviour is altered to fit the concept. According to Kolb and Rubin et al (1990), the process of cognitive growth from concrete to abstract and from active to reflective, is based on this continual transaction between assimilation and accommodation. These occur in successive stages, each of which incorporates what has gone before into a new, higher level of cognitive functioning. The interpretation of this theory is used as a guide to illustrate how CAL tools can aid the intellectual development of information (section 3.3.2), demonstrating the importance of designing 'CAL' tools, to enrich the required stages of individuals' cognitive development.

Dewey (1950), addressed the outcomes of the learning process as being the 'purpose' which always starts with an 'impulse'. This involves:

- observation of surrounding conditions,
- knowledge of what has happened in similar situations in the past, a knowledge obtained partly by recollection and partly from the information, advice, and warning of those who have had a wider experience; and
- judgement which puts together what is observed and what is recalled to see what they signify.

A purpose differs from an original impulse and desire, through its translation into a plan and a method of action upon foresight of the consequences of acting, given observed conditions in a certain way (see Figure 2.9).
Figure 2.8 Piaget's model of learning and cognitive development
(source, Piaget 1961)

The Process of Experimental Learning

Figure 2.9 Dewey's model of experiential learning
(source Dewey, 1950)
When compared with Kolb’s model of experiential learning, Dewey’s model has components of impulse; observation; knowledge and judgement. Despite being cyclic, Kolb argued that, life is just a continuation of the cycle, with no indication of advancement. Dewey’s model by comparison, shows progression as purpose. According to Heinich and Russell (1989), this idea became a guiding objective and challenge to educators in the UK, where a new movement in curriculum development and teaching emerged around this idea. This movement focused on the design of experience-based educational programs using the principles of cognitive-development theory. The major task addressed by the curriculum programs was the translation of the abstract symbolic principles of science into modes of representation that could be grasped by people at a more concrete stage.

ii. Mental models

A mental model is, an individual’s mental representation of reality which receives all incoming information, interprets it and shapes the reasoning (Padulo, 1994). For Kim (1993), mental models represent an individual view of the world, including explicit and implicit understanding, they represent more than a collection of ideas, memories and experiences. According to Kim, the role of mental models in learning is central. They can help an individual to make sense of reality, but they can also restrict his understanding of that reality.

To associate this reasoning with the arguments about how teaching methods could facilitate the process of learning, one conclusion could well be that the teaching tool will be effective if it leads to improvement in the learners’ mental models, i.e., enabling the learner to better understand reality and the process between the components in that reality (Lierman, 1994). According to Senge and Fulmer (1993), ‘Mental models are rich in detail, but they are deficient in critical ways, and express themselves as intuitions and instincts that are difficult to communicate and share’.

It can therefore be concluded that for an experience to be effective, an underpinning condition is that it must truly capture a representation of participants’ mental models, rather than a representation of the real system, i.e., if learners will be able to better understand reality and the processes between the components in that reality. However,
changing the mental model of an individual is extremely hard, because the individual sees through them. According to Padulo (1994), the major reason mental models can affect so strongly what we do, is that they affect what we see. Therefore, difficulties in learning, do not always mean deficiency in the learning method. However, one way of identifying how individuals can be receptive to the processing of information through their minds is by understanding the concept of learning styles and their preferred style of learning, as described in section 2.4.

2.3.3 Conditioning or Behavioural Theory
The behavioural theory is a valuable guide for detecting the learning outcomes as a result of changes in the learners’ behaviour. This is supported by Bigge (1992), who described learning as a change in behaviour, and that behaviour is determined by its consequences. It is therefore by monitoring the consequences of learning that measures of the learning outcomes can be detected. Bigge described two variables that determine behaviour, these are: stimulus (or input); and response (or output). Based on similar descriptions in literature, ‘CAL’ can be regarded as the ‘stimulus’, and the change in behaviour / learning outcomes / consequences, as ‘response’. In this way, responses can be classified as measures of effective (or ineffective) learning through the use of CAL.

Mumford (1980), addressed the major aspects derived from Skinner’s behavioural theory, which influence what is sought in learning. Some of these aspects which are of relevance to this research are summarised below:

- Much of the behaviour (learning) is undertaken in the expectation of certain consequences (learning outcomes). However the way to change behaviour is to change the consequence. Consequences can be managed, i.e., that particular consequences can be designed and built into an activity. In learning, consequences can be built which reinforce the desired behaviour recurring. In support of this argument, further work undertaken in Section 3.3.3 to develop evaluation criteria, to demonstrate ways of detecting the consequences of learning as a result of using
CAL tools, and also to investigate whether the desired consequences have been achieved.

- Learning does not remain effective unless it is reinforced. Therefore for learning to be effective, educational methods must cater for learners to reinforce their knowledge gained either through the educational tools or by seeking alternative methods (see Luarillard’s framework, section 3.3.2).

- Learners become less effective in using a skill unless they continue to practice it.

- Behavioural theory supports the idea of receptive learning, during which the learners receive the completely defined content of what is to be learned in final form (see section 3.3.2).

- Whatever is to be learnt must be presented to the learner piece by piece, various responses are required (e.g., answering a multiple choice question), and all correct responses are reinforced. In programmed learning it is often assumed that simply telling learners when they are right is sufficient reinforcement. Reinforcement can involve a repetition of the same learning process, or can be a further illustration of the desirability of the new learning. This term has alternatively been known as feedback (Stammers and Patrick, 1975) or knowledge of results (Annett, 1969). Feedback as described by Stammers and Partrick, arises as a consequence of learner’s actions and has been distinguished as either intrinsic feedback (to describe the results of an action, where the feedback is generated from the same context as the action itself), or extrinsic feedback (to describe someone’s evaluation of an action, where the feedback is generated from a context external to the action itself. This type of feedback is of relevance to strategic development of CAL tools, and highlights the importance of learners’ feedback upon the learnt aspects).

The behavioural theory is relevant to this research as it demonstrates the importance of recognising the consequences that result from implementing CAL tools. By structuring the desired consequences and monitoring the learning outcomes, these tools can be modified to better produce the desired outcomes. Reinforcement is emphasised by the behavioural theorists and is proposed, in section 3.3.2, as an essential factor for developing effective learning strategies via the use of CAL tools.
2.4 LEARNING STYLES

‘Cognitive style’, ‘Learning style’ and ‘Conceptual style’ are related terms which refer to an individual’s characteristic and consistent approach to organising and processing information (Tenant, 1997). According to Riding (1996b), learning styles reflect the fundamental make-up of a person, and have a physical basis. An individual however, will not be conscious of their style since they will have experienced no other.

Literature reflects the numerous attempts to classify the basic ways in which learning styles differ, each using different terms to address these styles (Messick, 1993, Smith, 1983, Squires, 1981, Riding, 1996b, Kolb and Royce et al, 1995, Honey and Mumford, 1982, Scriven, 1995, Sanderlands, 1988). Theorists also agree that an individual’s style significantly affects the manner in which information is habitually processed during learning and thinking, and this can have a significant effect on the efficiency and effectiveness of learning. However, one of the main concerns in this research is that, in designing and delivering educational methods, there is often the assumption that all individuals learn in a similar manner. This approach ignores the important issue of differences in learning style. Accordingly, the rest of this section defines the learning styles addressed by the experiential and cognitive schools of thought, and highlights their important role in producing effective learning.

2.4.1 Experiential Learning Styles

Section 2.3.1 of this chapter, addressed the relevance of experiential learning to learning in construction, and suggested the use of computers as a source of experience. Habeshaw (1990), adopted Kolb’s theory and produced a list of abilities associated with each stage of Kolb’s learning cycle (section 3.3.1), as illustrated in Figure 2.10. Kolb (1984) and Kolb and Rubin et al (1990), and addressed such abilities as ‘learning styles’. Kolb (1984) suggest that, ‘in any learning there is a conflict or tension between the polarities of at least two dimensions. The first of these dimensions has the concrete here-and-now experience at one pole, and abstract conceptualisation at the other (feeling versus thinking). The second dimension has practical action and experimentation at one pole and detached reflective observation at the other (doing
Figure 2.10 The abilities associated with each stage of the learning cycle (source, Habeshaw 1990)
versus watching). This tension between the polarities, generates four basic learning styles: Converger, diverger, assimilator, and accommodator. The divergent learning style is associated with valuing skills. Assimilation is related to thinking competencies. The convergent learning style is associated with decision skills. The accommodative learning style encompasses a set of skills associated with doing things. To identify individuals' learning styles, Kolb (1984) developed an approach called the 'Learning Style Inventory', described in Appendix A. The most important features of this approach, is that the learning styles are closely linked to the model of the learning process, presented in Figure 2.3.

Similarly, Honey and Mumford (1986) diagnosed four learning styles associated with the four stages of learning referred to in section 2.3.1-iii. These styles are referred to as 'Activists', 'Reflectors', 'Theorists', and 'Pragmatists'. A list of the abilities associated with these styles is shown in Appendix A and the questionnaire produced to assist in detecting individuals' learning style preferences as described by Honey and Mumford. Honey and Mumford (1989) stressed that "knowing about different learning style preferences is the key to understanding and to becoming more efficient at learning from experience ...sometimes we deliberately try new and different ways of doing things in order to learn". According to Honey and Mumford, 'ideal learners' comprise all abilities associated with these styles and have abilities to "review their experiences, describe the steps they go through to learn from experience, openly share their experiences, respond flexibly to the unexpected; reach conclusions via careful thought, have detailed recall, bridge the gap between artificial situations and reality; put deliberate effort into learning; ask questions; listen patiently; express thoughts fluently, are open to new angles, possibilities; identify their own development needs; can convert ideas into feasible actions; take risks; see connections, ask for feedback; adjust quickly to new, unfamiliar situations; make specific action plans; convert criticism into constructive suggestions for improvement".

Literature shows very little research has been undertaken to demonstrate the linkage between learning styles and individuals' performance in the construction field. However, Kolb and Rubin et al (1990) identified a number of factors that can influence
an individual style of learning, which are evidenced by the work of previous research in construction, these are:

- **Educational specialisation.** Undergraduate education is a major factor in the development of individuals' learning style. When there is a mismatch between the field's learning norms and the individual's learning style, people will either change or leave the field. For example, Lowe (1992) adopted Kolb's theory to investigate the learning styles of novice Quantity Surveyors. Lowe concluded from his research that, the preferred learning style of the novice quantity surveyor is that of the Diverger. According to Kolb, Divergers have qualities opposite to Convergers.

- **Professional career.** The person's current job role is considered as a factor that tends to shape a person's adaptive orientation. The tasks requiring specific skills will to some degree influence the expression of the learning style associated with those skills. The most specific and immediate level of forces that shape learning style is the specific task or problem the person is currently working on. Lansley (1987) utilised Honey and Mumford's questionnaire to formulate a profile for the typical middle manager and professional in the UK construction industry (see Table 2.1). These he states "differ markedly from the typical profiles for other occupational groups studied by Honey and Mumford".

Comparison with other occupational groups reveals that whilst the spread of scores on each dimension for construction is similar to the spread for other occupations, in many cases the styles are significantly different. Construction Managers have significantly higher Activist norms than managers in areas of finance, production, research and development and significantly lower norms than salesmen and managers involved in training. Their Activist norms are similar to those found for engineering and science graduates, and for marketing managers. On the Reflective scale they have significantly higher norms than production and training managers and salesmen and significantly lower norms than finance managers. They have norms which are similar to those of engineering and science graduates, marketing managers and salesmen and significantly lower norms than finance managers. Table 2.1 shows a comparison of norms for construction managers and professionals with those for a wide cross section of other
managers and professionals in the industry (Lansley 1987). This example illustrates how individuals style is influenced by their professional career.

<table>
<thead>
<tr>
<th>Construction (n = 104)</th>
<th>Active</th>
<th>Reflective</th>
<th>Theorist</th>
<th>Pragmatist</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>8.7</td>
<td>14.0</td>
<td>14.5</td>
<td>15.0</td>
</tr>
<tr>
<td><strong>S.D.</strong></td>
<td>2.9</td>
<td>2.8</td>
<td>2.6</td>
<td>2.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Others (n = 1302)</th>
<th>Mean</th>
<th>Reflective</th>
<th>Theorist</th>
<th>Pragmatist</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>9.3</td>
<td>13.6</td>
<td>12.5</td>
<td>13.7</td>
</tr>
<tr>
<td><strong>S.D.</strong></td>
<td>2.9</td>
<td>3.1</td>
<td>3.2</td>
<td>2.9</td>
</tr>
<tr>
<td>&quot;t&quot;</td>
<td>-1.99</td>
<td>1.4</td>
<td>6.27</td>
<td>4.4</td>
</tr>
<tr>
<td>prob</td>
<td>-5.0%</td>
<td>&lt;20.0%</td>
<td>&lt;0.1%</td>
<td>&lt;0.1%</td>
</tr>
</tbody>
</table>

Table 2.1 Comparison of norms for a wide cross section of Managers and Professionals in the UK industry

- **Adaptive competencies** Each task requires a corresponding set of skills for effective performance. The effective matching of task demands and personal skills results in an adaptive competence. Kolb and Rubin et al (1990) developed a “competency circle” describing specific competencies associated with each learning style. Kolb and Rubin et al studied two different samples of engineers and social workers. These results indicate that professions with a technical or scientific base, such as engineering, have people with primarily Convergent learning styles (Figures 2.11 and 2.12). Kolb and Robin et al also adopted previous research results of students learning styles, characterised by the subject matter in different areas, in a small western college at the university of Illinois and those of American Colleges and Universities. These results show that, in an undergraduate college, (of managers who have completed or are still in college), the learning style of engineers on average fall in the Convergent quadrant, bearing in mind that this may differ between civil engineers, electrical or mechanical engineers (Figures 2.13 and 2.14). Kolb and Rubin et al also highlighted the work abilities associated with the graduate engineers, are of convergent learning styles. Kolb and Rubin et al
Figure 2.11 Average LSI scores on Active Reflective (AE - RO) and Abstract/Concrete (AC - CE) by Undergraduate College Major (source, Kolb and Rubin et al 1990)

Figure 2.12 Learning scores for Variations Professional Groups (source, Kolb and Rubin et al 1990)
Figure 2.13 Similarities Among 36 Academic Specialties University of Illinois (source, Kolb and Rubin et al 1990)

Figure 2.14 Concrete/Abstract and Active/Reflective Orientations of Academic Fields Derived from the Carnegie Commission Study of American Colleges and Universities (source, Kolb and Rubin et al)
concluded that the persons' current job role is a factor that tends to shape their adaptive orientation. It was found that technical jobs, such as engineering, require technical and problem solving skills and demand a convergent learning orientation.

This section concludes that, individuals' learning styles can be developed, shaped and influenced by individuals' undergraduate domain, jobs or professional career. Also, that the abilities associated with the study of a subject matter, the academic orientation and the professional competencies play a role in shaping individuals' styles. Therefore, by recognising individuals' learning styles, educators are able to direct the learning process to enhance the targeted abilities associated with the future graduates within the construction field. For example, by recognising the convergent abilities associated with the Civil Engineers, the task of the educator will be to organise the process of learning to enhance the abilities associated with this style of learning. In this way individuals will improve their existing style, if matched with the required ones, or they will adopt to the new situation and shape their learning style if different. These conclusions are evidenced by Powell and Newland (1993), who implemented a computer based exercise, after studying the learning approaches of a group of Architectural designers with different learning styles. Powell found that, when an information system is successfully matched to people's ways of learning it seems to engender better communication and deeper learning. Powell's approach is described in more detail in section 3.3.1. Drew and Work (1998) strongly argued that effective learning outcomes depend on individuals' learning styles and information delivery matches, the skills and inherent abilities learners have when entering the learning situation, and the efforts they make to participate in opportunities and utilise resources available in education.

The recognition of these factors puts pressures on curricula developers to organise the educational tasks which will assist learners in their undergraduate courses to reach their educational goals. Educators must also recognise their own learning styles, which may be different to their learners' learning styles. It is equally important that educators recognise the expected competencies forced by the domain of learning, which will enable them to direct the process of learning for their learners to achieve these competencies.
Based on the assumptions that the abilities associated with novice Civil Engineers are those of a Converger and novice Quantity Surveyors are of a Diverger, these conclusions form a guide to the study of this research in the subsequent chapters. One of the key measures of the effectiveness of Computer Assisted Learning is their capabilities of promoting, developing or reinforcing individuals' learning styles. Chapter 4 addresses computer based simulation games as suitable tools for enhancing the convergent abilities associated with novice civil engineers, Chapter 6, addresses Multimedia tools as suitable methods for enhancing the divergent abilities associated with novice quantity surveyors.

### 2.4.2 Cognitive Learning Styles

Literature shows that cognitive theorists, address learning styles as an indication of how people differ in ways of translating information received. For example, Riding (1996a), diagnosed two independent dimensions of cognitive styles. A person's position on one dimension of learning does not affect their position on the other. However the way they behave, results from the joint influence of both dimensions, indicating how people differ in two basic ways. These are illustrated in Figure 2.15, and described below:

a. **The Wholist-Analytic dimension** This determines whether individuals take a whole view of things or see things in parts. This dimension, affects the way in which people think about, view and respond to information and situations. The strength of the Wholist is that when considering information or situations they see the whole ‘picture’ and can see situations in their overall context. This will make it less likely that they will have extreme views or attitudes. The negative aspect of the style is that they find difficulty in separating out situations into its parts. By contrast, Analytics will see a situation as a collection of parts and will often focus on one or two aspects of the situation at a time to the exclusion of the others. Their positive ability is that they analyse a situation into the parts, and this allows them to come more quickly to the heart of any problem. They are good at seeing similarities and detecting difficulties. However, their negative aspects is that they may not be able to get a balanced view of the whole, and their exclusion of the
Figure 2.15 Two independent dimensions of learning diagnosed by Riding (1996a)
others may bias a situation out of its proper proportion. Intermediates are likely to be between the two. They are able to have a view between the extremes which should allow some of the advantages of both Wholists and Analytics. Figure 2.16 illustrates how the information might be perceived by this dimension.

b. **Verbal-imagery dimension** Whether individuals are outgoing and verbal, or more inward and often think in mental pictures or images. The **Verbal-Imagery Dimension** has two fundamental effects that have implications for behaviour, job performance, and relationships; the way information is represented, and the external/internal focus of attention, as described below:

i. **Representation.** This affects the characteristic mode in which people represent information during thinking; either verbally or in images. On this dimension people may be categorised as being of three types; verbalisers, bimodals or imagers. **Verbalisers** consider the information they read, see, or listen to, predominantly in words or verbal associations. **Imagers** read, listen to, or consider information, they experience fluent, spontaneous and frequent mental pictures either of representations of the information itself or of association with it. **Bimodals**, tend to use either mode of representation. All groups will use either mode of representation if they make the conscious choice, i.e., verbalisers can form images if they try, but it is not their normal, habitual mode. The dimension of style thus affects the processing of information and the mode of representation that individuals will adopt, and thus affect the types of task they will find easy or difficult. An important implication is that Verbalisers often learn better by reading text, and Imagers by looking at pictures.

ii. **External/Internal Focus** This influences the focus and type of an individual’s activity, externally and stimulating in the case of Verbalisers, and internally and more passive in terms of Imagers. This has implications for the social relationships, and also for the type of work and environment people will be content with. For **Verbalisers** the focus will be outward to others and they will prefer a stimulating
Figure 2.16 Wholist-Analytic Dimension (source, Riding 1996a)
environment. They will see the social group as an extension of themselves and be socially aware. For Imagers, the focus will be more inward, and they will be more passive and content with a more static environment. They will view the social group as more distant from themselves, and may be less socially aware, see Figure 2.17. Appendix A describes in more detail the abilities associated with the four learning styles claimed by this theory, and will be referred to as a guide for the study undertaken in Chapter 7.

Figure 2.18 maps the learning styles generated by the dimensions of learning described above. The experiential learning style addresses individuals’ abilities associated with different stages of the learning process. Riding’s theory is considered a useful way of illustrating how educational tools can be used to facilitate and improve these strategies.

Riding’s `CSA’ (Cognitive Style Analysis) is seen a relevant, convenient and easy method, and is used to identify the learning style of undergraduate Quantity Surveying students, and to accommodate the relevant CAL tools which will help develop or improve their targeted learning strategies.

2.5 EFFECTIVE APPROACHES TO LEARNING

This chapter has developed an understanding of the learning process and the strategies that assist in developing effective learning. According to Garrigan (1997), the task of the educators is not limited to helping learners learn more effectively, but also to acknowledge and value the process of learning. This section, reviews the relevant approaches to learning, to enable this study to monitor the effectiveness of the learning process. The recognition of different approaches to learning can be considered as valuable guides to sustaining educational aims and objectives, through the introduction of new educational tools.

Bloom (1956) introduced a useful method of illustrating the hierarchy of the cognitive development, with definitions of each level, as shown in Table 2.2. This hierarchy consists of 6 levels of cognitive development. Levels 1-3 require a different ‘surface’ approach to learning than the higher levels. The surface approach is unreflective and is
Figure 2.17 The social implications of individuals’ dimensions of learning (source Riding 1996a)

Figure 2.18 Ridings’ map of cognitive styles (Riding 1996a)
characterised by the intention to learn facts (by rote). A deep learning approach is necessary for the higher cognitive levels and is characterised by understanding, reasoning, justifying and relating concepts to practice. In support of Bloom’s theory, Gibb (1990) highlighted several features which are associated with students adopting a surface approach (Table 2.3). This approach shows that the student is a passive spectator and is unable or unwilling to engage in academic learning or discussion. The deep approach pulls together the questionable challenges to ‘how well the educational methods develop high level of cognitive skills, and how can the interpersonal skills be included without overloading the curriculum allowing students to reach the higher level of the cognitive domain?’ These questions will be referred in Chapter 5 and 7 when evaluating the CAL tools addressed in these chapters.

Mumford (1980) argued that most of the learning theories concentrate on three steps that are generally easy to observe and comprises the process of learning. These are:

- Cue or stimulus, (what brings out the act of learning),
- Response or act/thought (what action takes place),
- Reward or reinforcement (what indicates that the action was successful).

Mumford argued that Drive or motivation / what causes the problem, is a fourth step. Motivation is a difficult element to detect, but it plays a central role in learning and therefore, it is important to understand how the wish to learn can be assessed. It can be argued that failure of the learning process does not only depend on the effectiveness of the educational methods introduced within the curricula, but also depends on the learners’ motivation. According to Bigge (1992), learners who are motivated, work purposefully and energetically. When a person develops a state of tension resulting from unsatisfied needs, it could be said that he is ‘de-motivated’. Mumford (1980) and Bigge (1992) defined two types of motivation; first, intrinsic motivation, that is, when a task is done because it is satisfying, or it carries its own reward, or it is done for its own sake. The second is extrinsic motivation, which occurs when a person pursues a learning task, but for reasons which lie outside it. When the learning goal is extrinsic, there ceases to be any point in remembering the learned material.
### Hierarchy of the Cognitive Domain

<table>
<thead>
<tr>
<th>Level</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Evaluation</td>
<td>Ability to make a judgement of the worth of something</td>
</tr>
<tr>
<td>5</td>
<td>Synthesis</td>
<td>Ability to combine separate elements into a whole</td>
</tr>
<tr>
<td>4</td>
<td>Analysis</td>
<td>Ability to break a problem onto its constituent parts and establish the relationship between each other</td>
</tr>
<tr>
<td>3</td>
<td>Application</td>
<td>Ability to apply rephrased knowledge in a novel situation</td>
</tr>
<tr>
<td>2</td>
<td>Manipulation</td>
<td>Ability to rephrase knowledge</td>
</tr>
<tr>
<td>1</td>
<td>Knowledge</td>
<td>That which can be recalled</td>
</tr>
</tbody>
</table>

**Table 2.2** (source, Bloom 1956)

### Course characteristics associated with student approaches to learning

<table>
<thead>
<tr>
<th>Surface approach</th>
<th>Deep approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>A heavy workload</td>
<td>Student recognising a need to know</td>
</tr>
<tr>
<td>Relatively high class contact hours</td>
<td>The teaching requires the active involvement of the student in the learning</td>
</tr>
<tr>
<td>A lack of opportunity to study subjects in depth</td>
<td>Interactive with others to maximise discussion</td>
</tr>
<tr>
<td>A lack of choice over subjects and study methods</td>
<td>The learning uses existing knowledge and experience</td>
</tr>
<tr>
<td>A threatening and anxiety provoking assessment system</td>
<td>Interdisciplinary approach to learning</td>
</tr>
</tbody>
</table>

**Table 2.3** (source, Gibb 1990)
However, to recognise the learning opportunities that help increase motivation, the following characteristics need to be present:

- The capability of being satisfied with current levels of performance, knowledge, skills or attitudes.
- The capability of recognising that activities can have more than one purpose
- The belief that it is possible to learn by planned action rather than by accident.
- The belief that the culture in which learners work, and particularly their superior, will give some support and some reward.
- The belief that recognising learning opportunities will lead to an improvement which they desire to make.

According to Bigge (1992), better motivation is created when the course objectives are discussed with students, despite the educator’s knowledge of what an average student can and will achieve. Evans (1992) argued that, reflection (defined in section 2.3.1 -ii) is a search for what has been learned. Most certainly it encourages, and generates a powerful motivation to learn more. Therefore, the desire to learn and improve skill levels and the need for simulation provided by uncertain and risky environment are a basic ingredient for promoting an effective learning process. Such understandings of motivation, will help with the study in Chapter 3 (section 3.3.1), when addressing strategies for enhancing the effectiveness of Computer Assisted Learning tools in construction.

2.6 SUMMARY

Literature reviewed in this chapter suggested that ‘Experience’ is a key element to learning, and learning in construction in particular, and that experiential learning can be promoted when learners are given the opportunity to interact with direct or simulated experiences ‘on the job’ or through the interpretation of experiences ‘off the job’. Research also shows that computers and simulation games are sources of experiential learning.
With the invasion of the new technology, it is within the interest of this research tooverview measures and strategies for effective use of the new technology within thecurricula, which will promote experiential learning in construction. However, literatureshows no such thing as theories of learning with computers. The study of theexperiential learning theory aids the understanding of the process of learning fromexperience. This will help the future investigations of this research, as to howComputer Assisted Learning tools promote ‘learning’ and learning for improvement inconstruction, based on the followings conclusions:

- Experiential learning offers a foundation for life long learning, which involvesactive exploration of experiences. Learning from experience is a cyclical process,which starts with a problem situation, followed by reflection, then forminghypothesis and finally testing these hypothesis in a new situation. Learning can startat any of these stages, depending on the learners’ needs and goals. Therefore, foreffective development and implementation of educational methods, an individuals’needs and goals must be recognised.

- Each stage of the experiential learning process generates associated abilities,forming learning strategies. In recognising the learners’ needs, and the associatedstrategies, this enables the educational tools to be effectively structured anddeveloped to target these strategies.

- Reflection is a key element of experiential learning, for both learners’ andeducators by reflecting upon experience, the lessons gained from the engagementof such experience can be learnt and applied in a new situation. Based on theseprinciples, educational methods can be implemented more effectively within thecurricula, when the time is taken to reflect upon the learning outcomes.

Cognitive development
The construction industry, like many others, requires individuals with cognitive andintellectual abilities. Therefore, to implement educational tools which will promote suchabilities, understanding of the cognitive theory helps identify the cognitive processing of information through the mind. While the process of cognitive
development is associated with the changes of insight in view of the gained experience, this highlights the importance of targeting the educational needs, through the presentation of instructions or different modes of information. Below is a summary of the main key points gained from cognitive theory, which are relevant to the objectives of this research.

- The cognitive processing of information can be defined in stages, where different abilities and learning strategies are generated from each stage.
- An effective educational tool, must not only keep the tension balanced between what learners already know, but need to add knowledge to their existing cognitive structure (assimilation), and/or alter their cognitive structures and fit in new objectives (accommodation). The understanding of these terms, makes a clear distinction between the ‘initial learning’ and ‘learning for improvement’, which helps the educational objectives to be effectively delivered.
- The key element in the cognitive development, is the development of ‘mental models’ or changes to old ones. Learning does not occur if changes to the mental model fail.

**Behavioural theory**

The behavioural theory presents good guidance to monitoring and evaluating educational media. This theory addresses learning as a change of behaviour, which is detected through a stimulus response relationship. Within the context of this research, it is the educational media which is considered as the ‘stimulus’, and the learning outcomes as ‘responses’. Accordingly, behavioural theorists stress that:

- For learning to be effective it must be reinforced.
- The change in behaviour can be monitored through feedback.

**Learning styles**

- Each stage of the experiential learning and the cognitive learning process generate abilities and learning strategies that are associated with them. Experiential learning styles are associated with the strategies developed from experience. Cognitive
styles address the abilities associated with the interpretation of the received information.

- The learning process is directed by the individual needs and goals. Therefore, learning styles become highly individual in both direction and process. Therefore, learners must recognise their learning needs and goals; failure to do so, limits learning.

- Professionals are likely to have different learning styles from novices within the same discipline. Learning styles can be shaped and influenced by various factors such as, educational specialisation, profession and work experience.

- Previous research shows that learning is most effective, when educational tools are developed to suit individuals’ learning.

- Previous research also shows that, the adaptive competencies and the learning style of novice Civil Engineers are convergent, and that the learning styles of the novice quantity surveyors are divergent.

- Recognising individuals’ learning styles, is the key to the development of effective educational tools.

**Effective learning**

- Recognising the different approaches to learning, helps sustain the targeted educational aims and objectives.

- A surface approach to learning, features passive learning situations, and learners are unwilling to engage in a learning situation. A deep approach to learning is characterised by active engagement in the learning process, and the understanding and recognition of concepts and relating them to practice.

- Effective learning does not only depend on effective implementation of educational tools, but it also depends on learners’ motivation. Motivation is an important element to progress in learning.

- Reflection is a factor for increasing motivation.

Based on the conclusions drawn from this study, Chapter 3 highlights the role of Computer Assisted Learning tools to promote learning in higher education, and proposes a strategic approach for effective development and implementation for these tools, to promote learning in construction.
CHAPTER THREE
EFFECTIVE LEARNING AND THE USE OF CAL

3.1 INTRODUCTION

3.2 COMPUTER BASED MEDIA
   3.2.1 History and background
   3.2.2 Classification of computer based media
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3.3 RESEARCH AND APPROACHES TO STRATEGIC USE OF CAL
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3.4 SUMMARY
3.1 INTRODUCTION
The Dearing report 1997, addressed the use of Computers and Information Technology in higher education, to have a central role in maintaining the quality of higher education. However, the use of the new technology over the past few years, and the implementation of the new technology and innovative teaching and learning methods, implies significant dangers in attempting to implement complex curriculum change through central direction without a considerable degree of planning and preparation. Therefore, to ensure that computers play this role effectively, a strategic approach must be adopted, focusing on the promotion of students' learning and tailoring the learning experiences to the needs of individuals or groups of individuals (I.T. and Dearing, 1997, Shield, 1999).

Accordingly, this chapter:
- develops a link between the use of different types of computer courseware, and their role in assisting the educational process in construction;
- proposes strategic approaches for the development and implementation of computer assisted learning tools for learners, guided by measures of effective learning described in Chapter 2.

3.2 COMPUTER BASED MEDIA
This section reviews the history and background of the educational use of computers in higher education, describes the types of media classified by different authors, and addresses their use in construction.

3.2.1 History and background
The basic principles of CAL were first advocated by Socrates, as a formal method of teaching. The Socratic method disappeared for over two millennia until the 1950's. It
was then revived in the form of Programmed Learning ‘PL’, but this failed to become established (Watson, 1987). In the 1950s and 60s, other methods were devised, such as teaching machines and various sorts of PL text books, and there was a mushrooming of PL publishing at that time. For many reasons (economic, logistical and technical) PL largely disappeared from the mid 60s, although it continued in a few specialised areas of teaching and industrial training. During the 1970’s, PL transformed into CAL, but the computerised form was not capable of mass dissemination. Personal Computers appeared during the late 1970’s and considerable interest in computer programming was generated during the 1980’s as a tool for problem solving, which is a way of making one’s ideas explicit and the best proponent of this philosophy was Papert (Drage and Evans 1988). Papert (1980) suggested that, computers could radically alter the nature of education itself, if they were used in certain ways. Papert’s views were influenced by Piaget (see section 2.3.2). Papert tested his views of the main ways in which it was expected that computers could be used in education in the early 1980s. This was done by producing a drawing device as part of a programming language, which explored mathematical shapes and ideas, and helped develop certain aspects of mathematics (Watson, 1987).

One important landmark in the UK higher education during the 1980s, was the publication of the Nelson Report (Computer Board for Universities and Research Council ‘CBURC’, 1983). This report highlighted the inadequate provision of student workstations in the UK universities and stressed that the well-equipped campus in the early 1990s should have one workstation for every five undergraduates. Subsequently, the Computers in Teaching Initiative (CTI) was set up with funding for five pilot projects from the CBURC, who had commissioned the report. Further funding followed from the University Grants Committee (UGC) in 1985. The primary aims of the CTI was to encourage the development of computer-mediated training and learning in UK universities, to evaluate the educational potential of ‘Information Technology’ (IT) within the context of university teaching and to promote an enhanced awareness of the potential of IT among academics and students of all disciplines. Secondary aims concerned assessment of hardware and software and evaluation of educational software. Accordingly, 139 separate projects were selectively funded, for which the
total resources, as reported by Gardner (1988), amounted to over £9.5 million. This was increased by additional self-funded support to projects by host universities.

Other programmes such as the Teaching and Learning Technology Programme (TLTP) was launched by the Universities Funding Council (UFC) in 1992, to make the teaching and learning more productive and efficient by harnessing modern technology.

However, despite the great potential for implementing Information Technology (IT) in higher education within the construction domain (Aminmansuor, 1994), only a very small part of this potential seems to have been exploited through the TLTP, or other bodies and institutions as described in Section 3.2.3.

To aid the implementation of effective strategies of Computer Assisted Learning tools, tailored for individuals’ needs in construction, the following section describes the classification of computer-based software as defined by different authors, and their role in supporting the teaching and learning process within higher education.

3.2.2 Classification of computer based media

Literature shows that the classification of computer-based software, to support the teaching and learning process within higher education, varies. Prior to the 1990s, most arguments for the use of computers in education centred around five main kinds of use. Jones and Kirkup et al (1992), described the first three, as different types of CAL programs, while the fourth and the fifth are examples of using computers as study tools. These are listed below:

a. Individualised learning through programs that offer drill and practice. These were programs that did not attempt to teach, but assumed that the teaching had already been completed, and so they provide repeated practice in learning a procedure or gaining a skill or knowledge. Although drill-and-practice programs are still in frequent use in UK schools, their use in higher education is much more common in the USA than the UK.

b. Individualised learning through tutorials. In this use, a topic is presented through text, diagrams, animation and so on, with practice in the form of questions answered by the learner, who usually types in words, letters or numbers. The
program then instructs the learner whether they are right or wrong, and gives further explanation of the topic.

c. Simulation programs. These offer the students experience they may not otherwise acquire. This type allows users to change the values of variables in a model and displays the resulting behaviour of the system. Here students are expected to gain insight into the process they see being modelled. The students are more than spectators, and are invited to take on the role of experimenter or scientist, investigating results of making changes to particular variables.

d. The use of computers as a study tool in order to produce laboratory work and analysis, and data manipulation.

e. The use of computers to learn programming.

During the 1990s, such categorisation changed. For example; Laurillard (1993) categorised computer based media as being; 'Hypertext' (including multimedia resources), 'Interactive media' (including, simulations, Microworlds and modelling) and 'Adaptive media' (including Tutorial programmes, Tutorial simulation, Tutoring systems). Doughty et al (1995) describe the use of computers for the enhancement of learning and teaching as 'learning technology'. This includes computer assisted learning, multimedia materials and the use of networks and communications systems to support learning, but does not include basic applications such as, word processing.

Another classification of computer based educational media is produced by the Engineering Professor’s Council (‘EPC’, 1996), which includes: Computer-based drill and practice exercises, Computer-Aided Instructions (CAI); Computer-Based Training (CBT); Intelligent Tutoring Systems (ITS); Resource-Based Learning (RBL); Simulation, Multimedia (e.g. hypermedia); and Expert Systems. Table 3.1 shows a list of these categories, which are described in more detail in Appendix B.

The significance of these classifications, is that different types of computer based media instructions, promote several types or levels of learning. According to Gagne and Briggs et al (1992), there are five major categories of learning: Verbal information, intellectual skills; cognitive strategies, motor skills and attitudes. The main focus of this
---|---|---|---
Drill and practice programs | Hypermedia | Productivity tools | Computer based drill and practice exercises
Tutorial programs | Interactive media | Communication tools | Computer aided Instructions
Simulation programs | Adaptive media | Learning tools | Intelligent tutoring system
Study tools for laboratory work | | | Resource based learning
Use of computers to learning programming | | | Simulations

Figure 3.1 A summary of educational media defined by different authors

Research is to address the effectiveness of Computer Assisted Learning tools in promoting intellectual and cognitive learning, by facilitating 'off the job' and 'on the job' experiential learning in construction. According to Gagne, for cognitive strategies to be developed, there must be a chance to practice developing new solutions to problems. Gagne also suggests that, learning tasks for intellectual skills can be organised in a hierarchy according to: complexity; stimulus recognition; response generation; concept formation; rule application; and problem solving. The primary significance of the hierarchy is to identify prerequisites that should be completed to facilitate learning at each level. Prerequisites are identified by doing a task analysis of a learning task. Learning hierarchies provide a basis for the sequencing of instruction.

Unfortunately, it is not within the scope of this research to study all types of CAL tools (the stimulus), to show how the sequences of instructions within each types of CAL and the stages of learning it can promote. Chapter 4, however, describes a study of Computer Based Simulation Games, and the sequences of instructions that promote
the convergent learning styles, which helps enhance or promote the essential skills associated with graduate Civil Engineers. Similarly, Chapters 6 and 7, report a study of Multimedia Computer Assisted Learning tools, showing how different modes of instructions can assist in developing various modes of learning, particularly when task analyses are carried out.

3.2.3 Computer based media in construction

According to Denning (1992), 'Engineering' presents a major category of adult education that is critical to most aspects of modern society. However, the fundamental nature of engineering, including the construction domain, is similar to engineering, where certain cognitive processes such as problem-solving and reasoning are particularly important tasks. Like other domains, construction engineers must engage in lifelong learning in order to maintain their knowledge of their field. This domain consists of a number of professional groups, who have various professional commitments and practise. These include; Civil Engineers, Structural Engineering, Engineering Designers, Geotechnical Engineers, Construction Managers and Quantity Surveyors and so on. The key element for the transition of individuals within these groups from being novices to professionals, is experience as described in chapter 2. The source of experience differs. It can be practical involvement in the real life activities, i.e. 'on the job', or through the transfer of such experience, i.e. 'off the job' (section 2.3.1). The use of computers for Continuing Professional Development (CPD), in the construction industry, or to aid the educational process in higher education, is considered as a source of experience that holds the potential to promote both 'on the job' and 'off the job' types of learning.

Unfortunately, despite the broad use of computers in higher education to promote learning within the construction domain, such use is still limited in comparison to other domains, such as 'Medical science', 'Arts', 'Music' and 'Social science' (TLTP, 1996). However, the commercial use of educational courseware for teaching and learning purposes in construction, can be identified from literature. For example, simulation games are particularly popular to facilitate learning in construction management. They are used in industry as training tools to simulate real life
construction decisions in a safe environment. Similarly these tools are used in higher education, to support the conventional methods in raising awareness of the nature of decisions made in construction. Examples of such simulations are ‘MERIT2’, ‘AROUSAL’, Pyramid I & II, ‘Super Bid’, etc. These are referred to in more detail in Chapter 4, and are considered as tools that are capable of promoting ‘off the job learning’, as they simulate real life experiences. TLTP (1993), have also supported a limited number of projects to aid the learning process within different construction professional groups. For example: ‘GeotechniCAL’, which provides interactive tutorials for basic geotechnical studies, soil-structure interaction, foundation design, site investigation and simulated laboratory test for undergraduate civil engineering; ‘COMPACT’, which is a comprehensive suite of CAL programs (covering 14 topics on concrete technology and the design of concrete structure), for undergraduate civil, structural, architectural and building degree courses; ‘SURVEY’, computer simulation produced by the ‘Interact project’ designed for students who have been on a surveying course, and who understand the basic principles of traversing, setting-out, and adjustment. These are mainly multimedia applications, and are described in greater detail in Chapter 6.

A growing range of tailored applications of CAL tools are being developed in construction, to suit the specific needs of specific subject areas. Table 3.2 provides a summary of examples of such applications.

Although the range of tailored and commercial tools is growing, the Dearing report (1997) states that ‘the use of Computers and Information Technology is not effectively embedded in the day to day practice of learning and teaching in most higher education institutions’ and ‘the main reason is that many academics have had little experience in the use of information technology as an educational tool’. However, when reporting the learning outcomes of the COMPACT project, Joyes and Choo et al (1999) criticised the Dearing view and argued that ‘good CAL is already available and good approaches to teaching have already been published. Such material in the wrong hands makes a poor learning experience’.
### Table 3.2: Examples of CAL application within Higher Education

<table>
<thead>
<tr>
<th>Applications</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Reality techniques. To familiarise the students with building components. This is carried out by providing computer based archives, of live construction sites, readily accessed by students to aid the teaching process for: property surveyors, building surveyors, building students</td>
<td>University of Reading [Source: Finch, 1997]</td>
</tr>
<tr>
<td>A prototype multimedia system is developed for teaching Building Technology. Gives the user the option to consider building elements or components as graphics, drawings or photographs, to ensure that students can progressively learn to visualise real building elements from component drawings.</td>
<td>Liverpool John Moores University (Riley, 1997)</td>
</tr>
<tr>
<td>‘The virtual building site’ project (at stage 1). Illustrates the use of video, audio, animation, graphics and text together, to show the construction process from site clearance to the installation of damp proof course.</td>
<td>University of Westminster (Diston and Hoare, 1998)</td>
</tr>
<tr>
<td>‘The multiple media for measurement’ project</td>
<td>Leeds Metropolitan University (Ellis, 1997)</td>
</tr>
<tr>
<td>Teaching surveying through computer aided learning.</td>
<td>University of Nottingham (Smith, 1997).</td>
</tr>
<tr>
<td>• Computer Aided Learning for teaching structural design</td>
<td>(MacCallum, 1997);</td>
</tr>
<tr>
<td>• IES 4D.</td>
<td>Dublin Institute of Technology (Beattie, 1997)</td>
</tr>
<tr>
<td>• A computer simulation software for integrated building design; and Computer Aided Building design (CABD)</td>
<td>University of Strathclyde (Bridges, 1997)</td>
</tr>
</tbody>
</table>

Both arguments may be correct. Salomon and Perkins et al (1991) argued that there is a reciprocal relationship between media methods and learners, where each can
influence the other. Therefore, the approach undertaken in this study distinguishes between the effectiveness of CAL tools in construction, effective users, and how the combination of both can produce effective learning.

The following section highlights some of the approaches found from literature, addressing the importance of certain strategies that should be implemented to produce an effective learning situation, whether through the use of CAL or other educational tools. This will guide the development of a suitable strategy for implementing effective CAL tools to aid learning in construction.

3.3 RESEARCH AND APPROACHES TO STRATEGIC USE OF CAL

Clark (1998) suggested that creating CAL tools is expensive in comparison with the cost for a typical module or course produced in the conventional way of teaching. It is therefore essential to establish exactly which, if any, of the components of a module or course can be made cost effective through the use of computers. Clark also emphasised that ‘so far this needs-analysis has rarely been carried out before introducing CAL into the curricula’. Accordingly, he introduced a matrix which categorises different steps of educational activities, moving from incomprehension to understanding, including:

a. Unconscious Incompetence. Learners are unaware if there is something worthwhile to be learned. The first task of the educator is to awaken in the learner the realisation that there is something to be understood. This step is called ‘Arousal’.

b. The learner is now consciously incompetent. This is the state from which the serious task of learning can begin. This process is called ‘Instruction’.

c. The result is to make the learner Consciously Competent. ‘Practice’.

d. Unconscious competence. This is a state that is maintained by familiarity and use.

These steps have also been organised as activities on a learning ladder as shown in Figure 3.1. At the heart of the learning ladder is instruction, where the real strategy of the educational process shows. Clark argues the possibility that the technology can be of use to both educators and learners at this stage. can help the learner to discover
Figure 3.1 Clark’s Learning Ladder & Learning Matrix (source, Clark 1998)
what is causing the impediment to learning, then the time taken by the educator to resolve that learner's difficulty can be significantly reduced. This research supports Clark's thoughts in that, the use of the technology must target specific needs, and that a strategic approach which will ensure cost effective development and implementation of Computer Assisted Learning tools is needed.

Smith (1983) produced a useful model for embedding educational material within the curricula. Smith's model describes the stages involved in developing and implementing effective learning material within the curricula, as shown in Figure 3.2, and includes five steps. The first three steps involve identifying the needs / interests, goals / evaluation criteria, and resources / procedures. The fourth and fifth steps (i.e., resources and procedures, program format and activities) define the development stage, while the last step addresses the outcomes of learning. Race and McDowell (1993), identified four components necessary for learning to occur, these are want, do, feedback and digest. Milne (1995), adopted Race's approach relating the learning process to the use of CAL. Milne defined 'want' by questioning whether the CAL package supports the students' motivation, that is wanting to learn. 'Do' is defined by questioning what the students do with the CAL package. Milne, suggested that, in evaluating a CAL package, a list of what the students will do is to be made, and whether these tasks make the students think. 'Feedback' is defined by Milne, by questioning whether the students receive adequate feedback from the CAL package and whether such feedback will correct misunderstandings. The last measures defined by Race is, 'Digest'. This questions how the CAL package supports the students in digesting of the subject material, and how it helps the student integrate the learning with existing ideas and concepts, i.e., positive transfer.

In support of Johnson and Gatz et al (1997) 'Technology transfer tends to focus on the producer of the technology while much of the focus of diffusion relates to the end user of the technology'. According to Stoner (1996), there is no single right way to implement learning technology, because the complexity of change management is such that it is unrealistic to seek "universal solutions". Literature however, reveals different views proposing strategic approaches to the implementation of effective computer
Goals and Evaluative Criteria

Start

Needs and interests

Evaluation and Follow-up

Conduct Program

Program Format and Activities

Resources and Procedures

Figure 3.2 Smith’s Model (source, Smith 1983)
based learning tools. Stoner (1996) for example, developed a conceptual framework of a life cycle model of Learning Technology Integration as shown in Figure 3.3. This framework describes the activities in the Learning Technology Cycle which include, initiation of the problem, analysis and evaluation, selection of learning technology, design integration, implementation, monitoring and adoption of integration and forming a linear model. These activities are linked to the students’ motivational constraints and undergo evaluation and quality assurance in a cyclic manner.

All these approaches add value to the design or use of CAL tools within the curricula. However, none of these approaches, introduces a global method that addresses individuals’ role during these processes. It is therefore proposed that, for effective use of the proposed framework, the role of the parties involved at each stage must also be included. Figure 3.4a presents the development of CAL tools as a central task shared between the educator, developer and learner. This may vary according to the situation, and there may be other parties involved, such as the evaluator, graphic designer, programmer and so on (depending on the size of the project for developing CAL).

Figure 3.4b describes the proposed stages of the strategic framework developed in this chapter. These stages are defined as: the ‘planning’ stage, followed by ‘development and implementation’ and then the ‘evaluation’ stage. The rest of this section describes these stages, which are guided by the learning theories described in Chapter 2.

### 3.3.1 Planning for CAL

Planning for CAL is mainly the task of the educator. This is supported by Heinich and Russell (1989) who stated that, ‘the deliberate arrangement of experience(s) to help a learner achieve a desirable change in performance and the management of learning in education is primarily the function of the educator’. This section highlights the main factors that need to be considered at this stage.

**i. Identifying the needs for CAL**

One of the conclusions drawn from the study in Chapter 2 (section 2.3.1-iii) is that the experiential learning process is erratic and inefficient when personal objectives are not clear and individuals’ needs are not identified. Accordingly, identifying the needs for
Figure 3.3 A conceptual framework of a life cycle model of Learning Technology Integration within teaching
Figure 3.4a  A triangle presenting the central role of CAL to the educator, developer and the user
Figure 3.4b A strategic framework for the development and implementation of CAL in construction
CAL, is an important factor at the pre-implementation stage. Therefore, the educator must ask, `why would I need to implement CAL?' The answers to this question requires an exploration of the educators' problems in teaching and their students' problems in learning. In this way the need for CAL can be diagnosed. To illustrate this, Doughty and Arnold et al (1995) summarised some of the answers suggested by a large number of university lecturers as to why CAL is needed. These were categorised as being: the drive to improve the quality and effectiveness of teaching; the problems of time; the balance between research and other activities; the need to increase the attractiveness of courses in the face of 'competition' in the market; the need to cater for greater numbers of students, from varied backgrounds, to broaden access (and to offer non-traditional entry method) to courses, and to support different forms of transfer into HE; the need to provide more flexible patterns of learning, and finally the expectation of students that they will be high calibre researcher, top manager and brilliant orator rolled into one.

According to Draper and Brown et al (1994a), the importance of the educator's input for the design of a study is an explicit list of the teaching aims and learning objectives that an educational method is likely to meet. These aims should in any case be available, but if not then writing them down helps to clarify what is meant to be achieved and what would be useful to measure. Moore and Exley (1995) also produced a useful approach that can be adopted to identify the characteristics of CAL, problems tackled, and the range of skills transferred by some of these methods. Educators must also take the responsibility not only for 'what' but also for 'how' their students learn. Where the key aspect of a student's learning process is dialogue between the students and the teacher, dialogue must be an essential element of the teaching strategy (Laurillard, 1993).

This approach is adopted in the studies produced in Chapter 7, when setting a strategy for implementing a suitable CAL tool for teaching 'Quantity Surveyors Measurement Rules'.
ii. Identifying the targeted users

To help identify the targeted users of CAL, the factors listed below need to be considered:

a. **Level of education.** According to Salomon and Perkins et al (1991), the level of knowledge and skill that an individual possesses will affect the impact of specific media. Therefore, the learners’ level of education must be identified to avoid promoting oversimplified or complicated levels of information, introduced by a CAL tool.

b. **Educational background and subject domain.** It is wrong to assume that all students who require to achieve the learning experience introduced by CAL have previously done the same courses (Doughty and Arnold et al, 1995). Therefore, through targeting specific backgrounds, CAL can be planned to enable learners enrich their understanding of the reality and the development of ‘mental models’, described in section 2.3.2-ii.

c. **Age and years of experience.** Peterson and Thornton et al (1986) argued that, the characteristics and particularly limitations, of the older person may be attributed to a decrease in the speed with which the central nervous system processes information. Talland (1968) produced a forgetting curve for information received by different ages of trainees (see Figure 3.5). Learners with different ages however, are expected to have different past experiences. Such experiences may give advantages or disadvantages to the older learner. According to Stammers and Patrick (1975), previously learned specific skills will affect the degree to which new ones can be mastered. While older persons may have a general line of attack for attempting to solve problems which may be facilitated by a rigid and non adoptive strategy, the young person is more risky in decision making. Therefore, the learners’ age influences their performance in using CAL. Also, according to Cross (1981), learning programs should adapt to the ageing limitations of the learners.

These factors are of particular relevance to the study in Chapter 5, which investigates the effectiveness of MERIT2, and considers the participants’ performance, in relation to different age groups.
Figure 3.5 Forgetting curves of meaningful 3 letter words in repeated recall. Young men (N=20), aged 20-25, middle-aged men and women (N=40), aged 47-62 (mean 58); old men (N=20), aged 77-89 (mean 81) (Talland, 1968)
iii. Motivational factors

Section 2.5, identified individuals’ motivation as a key factor in effective learning. This section highlights the motivational factors that should be considered when planning for CAL.

a. Choice. Cross (1981), stressed that learners must have as much choice as possible in the availability and organisation of learning programmes. Jones and Kirkup et al. (1992) also argued that the individual’s choice is an important factor for motivation. That is, the choice that individuals make for wanting to learn, and wanting to gain something from a particular experience (i.e., intrinsic motivation). When evaluating the MERIT2 (Chapter 5), participants’ choice to take part in the simulation game, was correlated to their opinion of the game. Open access to the use of CAL is also considered as a motivating factor as a result of evaluating ‘QSMM’ in Chapter 7, giving the learners the opportunity to organise their learning.

b. Reward. This can be addressed by the educator asking ‘What is there in this CAL tool for my learners? How can I convince learners that the use of this tool will lead to their success?’ Merrill (1994) argued that learners’ realisation that they are making good progress towards their intended learning goals (rather than towards apparently arbitrary goals set by educators), is an element of reward and provokes motivation. One such example is the application of competition in simulation games (Chapter 4), and the fact that taking part in simulation games may result in winning, is rewarding. This approach is adopted in Chapter 6 when planning for the development of QSMM.

c. Attitudes and culture. Krathwohl and Bloom et al. (1964), considered the development of positive attitudes towards an activity as an observable change in behaviour. This can be observed as learners show willingness to attend events and actively seeking for participation in an activity. Educators and learners’ motivation to use CAL is also influenced by their attitudes (Hannan and English et al., 1999).

According to Draper and Brown et al. (1994b) ‘some students may believe that CAL is used by a lazy educator to save them having to fulfil their duties. Whereas others may believe that CAL is a new technology that they feel privileged to have access to’. Draper also argues that, learner’s attitudes may be influenced by a good
or bad piece of software or by their educators' attitudes. This could be because the use of teaching software becomes so well established that it is forced on some reluctant educator, and their dislike may become a factor in its own right. Therefore, it is important that the educator plans the means for changing the learners' attitudes and culture, when thinking of implementing CAL.

Puca and Schmalt (1999) stressed that the relationship between achievement motivation and performance is mediated by task enjoyment, which plays an important part in promoting individuals' intrinsic motivation. According to Milne (1995) 'learners' extrinsic motivation (section 2.5) can be created by the educator persuading them that the CAL package is important for passing their exam. Such persuasion by the educator may not be needed, if intrinsic motivation is present through the students appreciation of the relevance of the CAL package to learning'. It is therefore the task of the educator to plan the means of ensuring that the learner's attitude is positive when using CAL.

iv. Learning strategies

These strategies are addressed below:

a. Educational need. It is the task of the educator to question the desired strategies to be promoted by CAL, with reference to the original educational needs. For example Creanor and Durndell et al (1995) suggested a number of questions such as: ‘Which skills does this tool assist with? Will it enable the learners to develop practical skills? Will it encourage them to participate actively in learning and or fully understand certain material within a particular subject area? Will it help learning and remembering a series of facts? Will it encourage the learners' interest and competence in using IT methods, and so on’.

It is therefore the task of the educator to define the learning strategies and the targeted skills, that a proposed CAL tool is intended to enhance or improve. Accordingly, the relevant style of CAL can be chosen to address these strategies (see section 3.3.2).
b. Learning styles. Section 2.4.1, described how individuals have different learning styles that influence the way they learn. Such differences are also associated with social attitudes and behaviour (Tennant, 1997, Kolb, 1984, Mumford, 1993, Riding, 1996a). It is therefore important that the educators recognise the differences in the student learning styles and how CAL tools can be used to either reinforce or promote a desired style. For example, Powell and Newland (1993) introduced an idealistic approach to the delivery of CAL, by adopting Kolb’s theory when designing a ‘multimedia information system’. Powell’s approach matched the different learning styles of building design professionals, who were mainly engineers and architects. Powell divided these professionals into four groups according to their learning style preferences. This included, those who prefer learning by doing (the dynamic learners), those who learn by seeing/feeling (the focused learners), those who learn by watching (the contemplative learners) and those who learn by thinking (the rigorous learners), see Figure 3.6.

The main aim of Powell’s study was to confirm the importance of matching the style of information interaction or engagement with the designers’ preferred style of learning. Thus, when the information system has the right “interactive sensitivity” it communicates particularly well. Powell’s work won three British and one European award for quality in ‘Multimedia’ design.

Despite the idealism in Powell’s approach, there is a tendency for educators to teach others new material in the way that they themselves have learnt, and to assume that their students learn best in one particular way. On the other hand, Powell’s approach to design versions of CAL tools to suit each style of learning, seems impractical. It would be more realistic to define the learning strategies that meet the educational aims and objectives, and therefore use CAL as a tool to develop, promote or reinforce these strategies. For example, when Roy (1997) used Kolb’s Learning style Inventory to test the learning style of a group of students before and after receiving a CAL course in mathematics for three hours a week over five weeks, Roy observed a shift in the students’ learning styles from AC (Abstract Conceptualisation) to CE (concrete experimentation). Such evidence can be used to encourage educators within the construction field to help learners
Dynamic Messages:
Based on a simple 'throw away' model
Excite - What's in it for Me?
Allow for self-discovery
Give context to share
with someone else.

Rigorous Messages:
Based on an authoritative rule based model
Pre-test-Confirm present knowledge
Teach-Impart new paradigm
Post-test-Evaluate competence

Focussed Messages:
Based on nature/nurture embedded model
Motive-Why should We do this?
Give confidence
Affirm the positive and
Guide away from the Negative

Contemplative Messages:
Based on all pervasive model
Broaden Awareness
Allow for reflection
Draw understanding together into a conceptual whole

Feel
Dynamic Sensitivity
Focussed Sensitivity
Contemplative Sensitivity

Think
Dynamic Sensitivity
Focussed Sensitivity
Contemplative Sensitivity

Do
Dynamic Sensitivity
Focussed Sensitivity
Contemplative Sensitivity

Watch
Dynamic Sensitivity
Focussed Sensitivity
Contemplative Sensitivity

Each Quadrant's View of the Interactive Sensitivity Typology

Fire Escape Package
Informed by:
Simulation
Surrogate experience
Face-to-face discussion

Energy Case Study Package
Informed by:
Examples
Step-by-step details
Practise based Case Studies

Production
Dynamic Sensitivity
Focussed Sensitivity
Contemplative Sensitivity

Objective/ Observation
Dynamic Sensitivity
Focussed Sensitivity
Contemplative Sensitivity

Theoretical
Dynamic Sensitivity
Focussed Sensitivity
Contemplative Sensitivity

Hypothetical
Dynamic Sensitivity
Focussed Sensitivity
Contemplative Sensitivity

Informed by:
Procedures
Codes and experts
Well structured CBT

Energy Topic Package
Informed by:
Global Model
Primary Data Source
Comprehensive Research

Quality Portfolio Package

Figure 3.6 Summary of messages preferred by different designer learners (source, Powell 1993)
shape their learning styles, towards targeted learning abilities, through the use of CAL tools.

Accordingly, Chapter 4 describes how simulation games can be suitable tools for enhancing the convergent abilities. This suggests that individuals with such abilities would be expected to perform better when taking part in simulation games. Therefore, when effectively implemented, simulation games should be able to shift or shape these abilities towards other learning styles. Similar arguments are presented in Chapter 7, describing the use of multimedia CAL tools, suggesting the ability to promote learners’ divergent and imagery learning styles.

c. Levels of cognitive development and the use of CAL. Educators must plan the required level of learning to be simulated by CAL. Bloom’s theory (section 2.5), reflects on the hierarchy of cognitive skills development, starting with knowledge and moving towards the ability to apply knowledge and evaluate skills. To decide on such tasks, the functionality of different types and styles of CAL, and their role in promoting learning must be explored. For example, within the construction discipline independent learning can be problematic, mainly because the conceptual development that science and technology demand is difficult and even uncomfortable. The concepts involved are very different from, and often conflict with, common sense concepts. Certain types of CAL however, can be designed to cater for the learners’ experiencing scientific and technical difficulties by experimenting with a simulated situation that assists in turning what seems to be complicated, to common sense that can be reinforced in real life at a later stage (Wolpert, 1992).

Section 3.3.2 describes how CAL tools can be designed and structured to implement the plans discussed in this section.

3.3.2 Development and implementation of CAL
The development and implementation of CAL forms the second stage of the framework, which can be carried out in two phases. The first is designing the structure of the CAL courseware, and the second is deciding on the environment within which
this courseware will operate. The framework also proposes that these two phases are mainly the task of the CAL developer (i.e., the computer specialist). However, the educator plays an important role in driving these tasks. Watson (1987) stated that mutual respect between the educator and the developer is important at this stage. Where, clear communications between these two parties exist, well structured and effective CAL tools are more likely to be developed. The rest of this section describes the main factors to be considered at each phase.

i. The structure of CAL

The main issue addressed in this section is that, the development of CAL tools is not only about programming a piece of software which will run efficiently in a sound environment. It is also about developing a well structured tool that targets the educational aims and objectives addressed in section 3.3.1. However, to help achieve this, literature reveals little evidence showing how CAL can be structured and implemented to promote effective learning. Accordingly, this section develops a link between learning theory and the development of the structure of CAL to promote learning.

a. Feedback. According to the behavioural theory (section 2.3.3), learning occurs through associating the correct responses with the stimuli in their environment. Based on such principles, this theory brought out the importance of 'reinforcement', alternatively defined as 'intrinsic feedback'. This type of feedback is defined by Laurillard (1993), as the action generated from CAL itself and should be structured to help the users identify and correct misunderstanding. Milne (1995), identified two important types of feedback provided by computers:

- The first type is pre-programmed feedback produced from the computer courseware, in response to the students answering questions, and it tells the user whether they are right or wrong and gives some additional information.
- The second type of feedback provides a much richer resource for learning. This feedback occurs when students interact with models or simulations. They will receive feedback on the consequences of their actions and so are able to test out their ideas and discover, for themselves whether their ideas are adequate.
The importance of feedback also has been highlighted by Long (1969). Long drew attention to the relationship between teaching methods and objectives as shown in Figure 3.7. A spectrum of training objectives, from knowledge at one end, through skills, social skills and interpersonal skills, to self understanding at the other, is juxtaposed with a spectrum of teaching methods and learning situations, from the printed word through lectures, discussion, simulation, to experience at the other. The areas of congruence between methods and objectives, while simplistic, are related to the extent of feedback in the teaching-learning process. This suggests that the intensity of feedback designed to be given by CAL must be linked to the main aims and objectives initially set out by the educator.

Feedback is also considered as being a motivational factor. This is illustrated by Gardiner and Palmer (1997), who promoted the notion of feedback loops as a method of motivating students, described in Figure 3.8a. Each loop begins with some input, which can be an instruction or learning episode in the first instance, or subsequently feedback. After a period of interaction and reflection, work is produced and assessed. The progression of effort and feedback is shown as a series of ascending loops, each loop reaching a higher level of understanding and the end result being attainment of competence, (Figure 3.8b). The loop can stop when a time has expired, or a number of attempts have been made, or an acceptable level of competency has been reached.

Intrinsic feedback is considered an important feature to direct the individuals’ learning, and hence, to produce an effective CAL tool. This is evidenced by the study of Simulation Games in Chapter 4, and the evaluation of the MERIT2 simulation game described in Chapter 5.

b. Cognitive strategies. The main principles of cognitive theory were originally applied to discovery learning. The latter was addressed by Bruner (1961), as a matter of rearranging or transforming evidence in such a way that one is able to go beyond the evidence to additional new insight. The cognitive theory has also
Figure 3.7 Teaching methods, learning objectives and the significance of feedback (source, Long 1969)
Figure 3.8a

Figure 3.8b

Figure 3.8 Feedback spiral (source, Gardiner and Palmer 1997)
strongly influenced the ways in which computers solve problems, in relation to human knowledge and its influence is seen to be of two kinds.

- Knowledge of fact (*knowledge that*); and
- Knowledge of procedures or methods for solving problems and making inferences and judgement (*knowledge how*).

According to Gagne (1985) the way in which a person sets about solving a problem (*knowledge how*) is seen to be very dependent on what the person knows about the content of the problem (*knowledge that*). For example, students may know ‘that’ there is a building that has been constructed, and CAL can visually present ‘that’ building. However the importance of cognitively designed CAL tools would appear in showing ‘how’ this building has been constructed. This can be achieved within or external to CAL, to drive the exploration and/or instruction. Therefore, tasks and situations should be as realistic as possible, allowing for mistakes to be made, and providing help and guidance (Draper and Brown et al 1994b).

Spiro and Feltovitch et al (1992) formulated a ‘cognitive flexibility theory’ to support the use of an interactive technology domain, where the nature of learning is described as complex and ill-structured. The principles of this theory provide a useful guide addressing the factors required for effectively structured CAL which will assist in developing a high level of cognitive strategies, as described below:

- Learning activities must provide multiple representations of content;
- Instructional materials should avoid oversimplifying the content domain and support context-dependent knowledge;
- Instruction should be case-based and emphasise knowledge construction, not transmission of information;
- Knowledge sources should be highly interconnected rather than compartmentalised.

The principle of this theory is referred to in Chapter 5 (evaluating of MERIT2) and as a guide in Chapter 7 (the development of QSM1).
CAL must also be structured to target the required level of cognitive development (such as remembering and recalling knowledge, thinking, problem solving, creating), addressed in Bloom's theory in Chapter 2. These levels are also seen as being closely linked to Piaget's idea of assimilation and accommodation (section 2.3.2). Where CAL can be incorporated to balance the tension between these two processes, through the recognition of the cognitive stages addressed by Piaget's learning cycle in Figure 2.8.

c. Facilitating experiential learning. Experiential learning is a meaningful discovery, which ought to be planned, controlled, actively explored and evidently reflected so that the learner can value the gained experience (Boydell, 1976, Kemmis and Atkin et al, 1977, Gibbs, 1990). According to Roger and Freiberg (1994) the capability of some CAL tools to simulate real life activities can be achieved when: learners participate completely in the learning process and have control over its nature and direction; learning purposes are clarified; and learning tools balance intellectual and emotional components of learning.

The structural development of CAL, however, may be influenced by the instructions provided to a learner, proceeding from direct representations of experience (as in images, video clips, animation and so on), through symbolic representation (as in words). Therefore, the sequence in which a learner encounters materials has a direct effect on achievement of mastery of the task. However, it is important that in the presentation of learning material, the learners' current level of experience is determined. While learners need experiences that allow them to test their ideas and practice their skills through learning by trial and error, the tasks or the doing (within CAL) should also be relevant to the learning outcomes. Learners must also be actively engaged, rather than passively, to find paths to answer (Milne, 1995).

This research however, strongly supports Laurillard (1993) in that effective learning occurs when all the stages of the learning process are simulated. However, not all computer based media methods, are capable of simulating all stages of the learning process. For effective learning to occur, other educational media must be
used to complete the learning process. Laurillard introduced a list of terms describing educational media (including CAL) when any of the followings apply:

- discursive, when a medium that supports discussion between learners, or between learners and the educator;
- adaptive, when computer programs are capable of using information about learner’s performance on a task, or series of tasks, to determine the form of the subsequent teaching, or the exercises set for the learners;
- interactive, when the computer’s capability to be programmed to change its behaviour according to the learner’s input;
- reflective, for teaching methods or activities that encourage the student to reflect on what they know, or on what they have experienced.

Using these characteristics of the learning process, Laurillard produced a ‘conversational framework’ shown in Figure 3.9. It can be seen that the adaptation (activities 5 and 10) and reflection (11 and 12) are internal to both the educator and the learner, and characterises the two levels of their dialogue as discursive, i.e. interactive at the level of descriptions (activities 1 to 4), and interactive at the level of action (activities 6 to 9). According to Laurillard, this framework is intended to be applicable to any academic learning situation, to the full range of subject area and types of topics. It is not normally applicable to learning through experience. Although experiential learning has ‘adaptive’ and ‘reflective’ components (chapter 2), the ‘conversational framework’ identifies those as conscious processes accessible to the learner to consider and modify. Appendix C shows the types of computer based media addressed by Laurillard, and how these facilitate different stages of the learning process in relation to the conversational framework shown in Figure 3.9.

It is therefore important to recognise which stage of the learning process, a CAL tool is intended to support, and what other educational media can be used to support the full process of learning. Laurillard’s approach is referred to at various stages of this study, when describing Simulation Games and Multimedia applications to support learning in construction.
Figure 3.9 The 'conversational framework' identifying the activities necessary to complete the learning process. (Source Laurillard, 1993)
d. Designing the levels of interaction. According to Arnott and Young et al (1993), 'a rich and simulating learning environment which fosters student's enthusiasm, involvement and self-reliance, can be achieved through the use of CAL, if it is a well designed and useful courseware in itself. This will undoubtedly provide considerable motivation to users'. Arnott and Young et al highlighted the important features that should be present to allow for learners' interaction with a CAL courseware. These are summarised below:

- Encouraging the learners' motivation and engagement by providing a variety of interactions and avoiding repetitive tasks.
- Learning tasks and activities executed by the learners should be capable of being explicitly linked to the learning objectives.
- Learners should be either directed by the educator to how they ought to progress through the courseware or how they should be given the choice to explore and discover the material themselves.
- Learners also have the responsibility in deciding what information they require to attain the goals they have been set. One way of doing this is by providing a 'concept map', which allows the students to exercise this responsibility through the control they have in navigating around the various layers of the 'concept map', and example of this is shown in Figure 3.10.
- While allowing the students the freedom to move through the sections of the module, the students must be able to know where they are, where the relevant information can be found, and be able to gain view of the information available and its organisation.

Section 6.5 of this research, highlights some of the research undertaken to relate the effectiveness of 'Hypermedia and Multimedia' systems when designed to accommodate individuals' learning styles. This reflects the importance of designing the level of interaction within CAL tools, to promote effective learning.

e. The style of CAL. The style of CAL has a major influence on learners' motivation. Papert (1980) argued that, in certain exercises when computers take the role of an educator, leaving learners in total control of a situation, such a sense of control
Figure 3.10 Concept maps and the active learning environment
(source, Arnott et al 1993)
might lead to greater self-esteem and can be motivating in itself. Motivation in such situations is due to the sense of positive power which comes from the ownership of a skill or a knowledge and very closely aligned to self-esteem. According to Malone (1981), motivation is correlated with challenge, that is by defining clear goals, or by the score keeping and to the ability of a computer program to stimulate curiosity. Curiosity is created by providing an optimal level of informational complexity, and the optimal level will depend upon the individual's current state of arousal or excitement. For an individual who is currently bored, it may take very little to happen in the world or on the computer screen before curiosity is aroused. For Malone (1981), the use of graphics and sound, or the introduction of a random element, leads to perceptual curiosity and to motivation to explore the world simulated by a particular computer program. Also, incomplete information and showing the learners how much they do not know is a factor to motivate them to find out more, which will lead to cognitive curiosity (Chapters 4 and 6, describe how simulation games and the style of multimedia tools influences the learners performance and their motivation to learn).

The features described in this section will be referred to later on in this research, when studying the efficiency of the CAL tools in Chapters 5 and 7.

ii. The operating phase

This section highlights a number of the environmental problems that need to be considered when implementing a CAL tool. Jones and Kirkup et al (1992), adopted a useful approach that can be used to identify the barriers that need to be overcome to provide efficient use of CAL, as shown in Figure 3.11. These include, technical and installation difficulties, networking and providing the required access. These barriers however, vary depending on the nature of the courseware and the environment it is intended to run within. Chapters 4 and 7, describe the main concerns addressed when running the CAL tools in this study.
Figure 3.11 Barriers to the use of CAL
(source: Jones and Kirkup et al 1992)
3.3.3 Evaluation of CAL

The evaluation of CAL forms the final stage of the proposed framework. The main aim of this section is to set a strategy for the evaluation of CAL tools, that links with previous stages of the framework and will ensure effective implementation of CAL has been carried out effectively. This enquiry is guided by methods of evaluation described by literature. For example Milne (1995) addressed three valuable aspects that should be considered when evaluating a CAL tool, these are:

- The correctness of the academic content;
- The ease with which the courseware can be accessed and used;
- The effectiveness of the courseware to support the learning process, in view of the aims and objectives originally set.

Literature also shows that the evaluation of educational methods are classified in two phases as described below:

**a. Formative evaluation.** According to Edwards (1995), this phase is undertaken during the production of the courseware, at each critical stage of the development. The overall concern here is that the courseware is being produced to meet the learning objectives and audience demands that were originally intended. Milne (1995) claimed that this stage is mainly concerned with the evaluation of the design and content of the courseware. To assist with the tasks to be undertaken during this phase, Reeves and Hermon (1993) produced a systematic evaluation procedure, represented graphically in Figure 3.12. This approach asks the users to give a score reflecting their satisfaction with different aspects of the courseware. This approach is adopted in Chapters 5 and 7 for evaluating different aspects of 'MERIT2' and 'QSMM'.

**b. Summative evaluation.** Edwards (1995), addressed the 'summative evaluation' as being the second phase of the evaluation process. It involves the establishment of the fitness of the courseware for use with the actual audience, who are to be given the opportunity to try it out in a learning situation and give back their comments.
Figure 3.12 A systematic approach to the evaluation of multimedia CAL tools (source, Reeves and Hermon 1993)
According to Milne (1995), ‘this phase involves assessing learning effectiveness of a CAL tool. We are looking:

- For indicators that predict whether students learn efficiently and effectively when using a particular CAL package;
- Whether learning effectiveness focuses on how learning is supported by the courseware;
- Whether the courseware supports critical thinking;
- Whether students are required to interpret and use ideas, skills and information, and whether they are asked to use (transfer) their understanding in new situations.’

The TLTP evaluation group Draper and Brown et al (1994b) produced a number of questionnaires that can be used to aid formative and summative evaluation of CAL tools. These include:

- A pre-task questionnaire to discover aspects of what each student brings to the session (e.g. prior experience, task purpose);
- Confidence logs after each kind of activity, usually with a baseline;
- Post task questionnaire to elicit personal reactions to the experience, and to ask about the relative value each individual put on various resources;
- Observations (by the evaluator, possibly using video);
- Focus groups or interviews with samples of students;
- Access to subsequent exam performance on one or more relevant questions.

Literature reviewed in this section provides a useful guide to the evaluation of the CAL tools under study in this research and are referred to in Chapters 5 and 7.

3.4 SUMMARY

Literature reviewed in this chapter highlights the growing use of computers in higher education, illustrating the limited use of CAL tools within the construction domain. Little has been reported on the teaching and learning strategies, focusing on students’ learning, and the development or implementation of CAL tools, to meet individuals’
needs and learning styles. Therefore, to raise awareness of the importance of recognising such strategies, one of the important issues raised in this chapter is that, not all media methods promote all the stages of the learning process. However, other methods may be required to complete the stages of the learning process.

To aid the effective implementation of CAL tools that target specific learning strategies which meet individuals' learning needs in construction, a strategic framework was proposed. This framework addresses the main factors that should be considered when planning, implementing and evaluating CAL tools, showing the interconnection between these stages. The distinctive feature of this framework among others produced by different authors, is that it defines the contribution of individuals within each stage of the framework. It also bridges the gaps between theories of learning (addressed in Chapter 2) and the strategies for effective CAL set in this study.

To test the validity of this framework, Chapter 4 develops a detailed study of computer based Simulation Games as an example of CAL tools that promote experiential learning (addressed in Chapter 2). Particular attention is paid to describing the MERIT2 simulation game as a CAL tool used to promote learning in construction. Based on this study, Chapter 5 investigates the effectiveness of MERIT2 simulation game, adopting the stages proposed by the strategic framework developed in this chapter.

The framework proposed in the study of this chapter is also used to strategically develop and implement a Multimedia CAL tool, to assist with the learning of quantity surveying measurement rules. This tool is then evaluated to test the validity of the strategies proposed by this framework.
CHAPTER FOUR

SIMULATION AND GAMING

4.1 INTRODUCTION AND BACKGROUND
   4.1.1 The development of simulation and gaming to date
   4.1.2 Terminology
   4.1.3 Advantages of simulation games
   4.1.4 Disadvantages of simulation games

4.2 SIMULATION GAMES AND THE LEARNING PROCESS

4.3 APPLICATION AREA OF SIMULATION GAMES
   4.3.1 Commercially available construction games
   4.3.2 Bidding simulation game
   4.3.3 Case studies

4.4 MERIT2
   4.4.1 Pre-implementation stage
   4.4.2 The development and implementation stage

4.5 SUMMARY AND GUIDE TO THE NEXT CHAPTER
CHAPTER 4

SIMULATION AND GAMING

4.1 INTRODUCTION AND BACKGROUND

The diverse nature of the construction industry implies that decisions confronting engineers and planners generally involve social, economic and technical considerations subject to a collection of complex constraints. The construction industry produces facilities which are unique, large and immobile, and thus are subject to variations in regional and weather conditions. The fact that constructed facilities must be erected at a given site, and in a specified time requires contractors to be flexible enough to mobilise sufficient productive forces into any area to perform the designated work, and adaptive enough to absorb the fluctuations in its work loads. Consequently, the management structure of contractors must be flexible and the need to make independent decisions must permeate the entire management hierarchy.

At the same time the courses offered by universities and colleges for instruction of engineers can usually only provide the basic theoretical knowledge required and 'on the job' training has to be carried out by the construction companies after the completion of such courses. This can mean that the time between graduation and becoming a useful member of a site team can be protracted. To understand the consequences of decisions within this construction environment, without paying the penalty associated with erroneous decisions in the real world, computerised construction games portraying social, economic, and technological decisions seem suited well for continuous professional development of engineers. Computer based-simulations games in construction offer the participants the chance to gain 'experience' by allowing him/her to get the feel of the construction environment. By using this medium, the participants can practice the techniques that are common to various construction situations. With this experience, such situations should be more familiar when they are encountered for the first time on the job site or in the office.
This chapter describes simulations games, highlighting their benefits and limitations as educational tools and their potential to facilitate experiential learning. A review of the commercially available simulation games in construction is also provided with particular attention to the MERIT2 computer based simulation game, which has been successfully running for at least ten years in the construction industry and academia. Case studies of the effectiveness of such simulations are also reviewed, revealing qualitative rather than quantitative measures of these tools. To achieve one of the main aims of the research, this chapter suggests a methodology for investigating the effectiveness of MERIT2 as a CAL tool, used to stimulate learning in construction management, within a simulated environment.

4.1.1 The development of simulation and gaming to date

The idea of games and gaming as a training tool is as old as the idea of competition. One of the first historically recorded uses of games to model a real-world situation dates back to the 18th century. Great military systems employed some rudimentary forms of war gaming, but the practice began to be formalised in the Age of Rationalism, primarily with the Prussians use of "strategic games" in the mid nineteenth century (Jones, 1987).

According to Stahl (1983), the writings of Sun Tsu, the great Chinese General of the 5th century BC, contained some elements of the theory of games. This included the use of elaborate scale models to suggest reality, the introduction of time as an element, the development of complex rules to simulate the environment, and the use of umpires to arbitrate disputes and score the results.

In the twentieth century, considerable use of war gaming was used in planning for World War II. Since that time there has been a flurry of activity in gaming research in areas other than military, such as business and education. In 1932, the first publication on business and educational games appeared in the USSR. The first Soviet business game, "an organisation of production" was developed at the Leningrad Engineering and Economics Institution. It was found that the game produced a program four times faster than high-level discussions and that it required only half the labour. The game
also allowed the players to assimilate some of the skills associated with the new technological system while the game was in progress (Stahl, 1983).

The considerable amount of routine calculation and the absence of computational aids in the USSR at that time, acted as a strong disincentive to the use of gaming and for the next 20 years the subject practically disappeared. Interest started again in the USSR in the 1960's, coinciding with the increasing availability of large computers. This made the USSR contribution not only to the introduction of the digital computers, but also, making the construction of extremely complex mathematical models of the game environment possible (Ellington and Addnill et al, 1981).

The first widely known management games were initiated in 1956 by the American Management Association (AMA) and by the University of California, Los Angles, (UCLA). UCLA developed Model No.1 on an IBM 650 computer to assist in teaching economics and business to undergraduate students. Like war games, there has been a trend to make the business games more strategic than tactical by increasing the scope of the game model. The encouraging results of the UCLA and AMA games led to improved simulation routines written for faster computers. The basic principles of management gaming were established in this period and remain substantially the same today. The success of gaming as a management training tool led to its adoption in many other fields, e.g. international politics and social conflict and urban land use planing (Elgood, 1993).

The growth of psychoanalysis and of communication theories has also promoted the employment of simulation techniques such as role play. But it was only with the introduction of new developments and with the development of video games, that a theoretical debate on the business and training possibilities offered by these new developments was initiated (Crookall and Klabbers et al, 1988).

Within the construction discipline, simulation games for education and training purposes have received increased attention during the last decade, particularly for construction management. Simulation games are now used at some Universities as standard educational tools and within some construction companies as training tools.
and thus have attained widespread application. Section 4.3, provides a review of some of the simulation games that are used for training purposes in the construction industry or in higher education.

4.1.2 Terminology

The terms ‘game’, ‘simulation’ or ‘exercise’ are often used interchangeably by different authors. To avoid confusion this section gives precise definitions to the concepts adopted in this thesis.

i. Simulations, games, role play, exercise:

A simulation is the process of designing a model of a real system and conducting experiments with this model for the purposes of either understanding the behaviour of the system or of evaluating various strategies for the operation of the system” (Shannon, 1975).

A simulation is likely to be used for purposes of predictions, because it seeks to model a specific situation with considerable accuracy. It is believed that it can give considerable information about what results would follow a particular decision taken (Gredler, 1992). According to Jones (1987) ‘What is called a non-interactive game is nearer to the concept of simulation… it is useful when describing an experience in which one participant succeeds or fails independently of another’.

A game could be considered as a magic kingdom isolated by its own rules from real world considerations and ethics. In games there is only one role—that of player—and it is the duty of the players to try to win while conforming to the rules and the concept of fair play which is an inherent aspect of the rules. Games clearly imply competition whereas simulations, role play and exercises are often co-operative events. The outcomes of a game cannot be a matter of opinion, it cannot be open ended. There must be a scoring mechanism to determine who has won and who has lost or a final score at the end. The word game often suggests learning and the increase of competence (Jones, 1987, Ellington and Addnill, 1981, Gredler, 1992).
An exercise is a title suggesting “the practice of something that has recently been taught, and a judgement about how well it has been done. There is a connotation control by some teacher or instructor which is less marked in the ideas of simulation, game or role-play. In an exercise the participants have no roles. As seen from the inside, the participant is a problem solver, a discusser, a puzzler, a decision maker. Unlike a game, the participants are not trying to win, they are trying to solve a problem” (Elgood, 1993).

Role-plays are episodic and brief. According to Kibbee and Creft et al (1961) ‘role-play enables the participants to gain insight into human relations situations by experimenting with various roles in a safe learning. Because it is spontaneous, flexible, and action-oriented, it provides a valuable bridge between principle and practice’. Role-play can be functional, in which case the word ‘play’ is inappropriate, or they can involve play-acting. Functional role play, if it has sufficient facts to allow for professional intent, is really a short simulation. The play type of role-play is a miniature informal drama.

Simulation games however, combine the features of simulations, games and role-play as presented in Figure 4.1.

According to Saunders (1987) and Fripp (1993) “the word ‘simulation’ is sometimes considered too mechanistic for educational purposes...however, ‘games’ can imply time wasting, not taking things too seriously and engaging in an exercise designed purely for fun”. The concept of simulation game seems to offer the right combination and balance between these extremes. The main differences between these concepts can be summarised as follows:

a. In a traditional operative simulation model the objective is usually to find the best possible solution to a particular problem, while a simulation game always has educational purposes (Stahl, 1988, Fripp, 1993)
Figure 4.1  A diagram describing how simulation games combine the features of simulations, games and role play.
b. In order to stress the educational goals, rather than the entertainment nature of games, the users of simulation games are called participants rather than players (Fripp, 1993).

c. Traditionally the experimental process with a simulation model has been expert driven. In a simulation game, participants can plan their own experiments, input parameters and follow what happens directly during the game (Thatcher and Robinson, 1984, Eriksson and Hellman (1988).

ii. Computer based simulation

Gredler (1992) categorised simulations into major types and groups based on the general nature of the dynamics of the interactions produced by the simulation. These are ‘business simulations’, ‘social simulations’ and ‘computer simulations’. This research focuses on computer simulation.

Some of the main characteristics of this process can be summarised as follows:

- The main purpose of computer-based simulation is to aid understanding of and/or to solve complex real-world problems by the use of a computer-based model which might be a small simplified version of the real system (Kelton and Law, 1991, Stahl, 1988).

- The main process of simulation is an expert-driven process. The process of analysing the real system, building a computer based model and analysing results demand a wide range of skills from managerial decision makers (Stahl, 1988, Goldstein, 1993, Marshall, 1988).

- The process includes a variety of activities which can be highly time-consuming depending of the goal of the simulation and the real system (Marshall, 1988).

- Reusability of results from different simulation projects is low which means that normally every new simulation project requires the execution of all the simulation activities from the beginning (Goldstein, 1992).

- The experimentation with a simulation model is an interactive process which includes activities such as: take action, receive results, reflect on results, make conclusions, change strategy and test in a new situation.
The emphasis of activities and efforts in the process lies on the use of computer facilities and exploring them maximally (Senge and Fulmer, 1993, Fripp, 1993, Goldstein, 1993).

The history of computer simulation as a discipline has its roots in the late 50’s with the introduction of ‘continuous simulation’ and system dynamics theory (Forrester, 1962). Discrete-event simulation appeared later, in 1967, with the release of Simula as a simulation programming language (Palme, 1970). Even though computer-based simulations existed in the area of education at the beginning of the 60’s, it took until the 80’s before their use had become more extensive in education (Saven and Villegas 1992). Simulation has witnessed increasing development in recent years and has become widely recognised as a valuable means of learning and training in educational environments such as schools and universities and also in industrial companies.

iii. Operative model, business games and simulation games

There are three types of computer-based models used for educational and industrial training purposes. There is no radical distinction between these types of simulation models, since they have many common purposes.

The operative model is the traditional type of computer-based simulation model used in supporting decision-making. It is expert driven and the interaction between a participant in the training and the simulation is very limited.

The second is business games which are a more sophisticated type of computer-based simulation model. Players of a business game will be co-operating or competing with each other or against the computer in order to achieve a particular goal. Players interact with respect to a particular game scenario and follow a set of rules or a game strategy (Muller, 1994).

A simulation game, can be defined as a traditional operative simulation model in the frame of a game, i.e., it is an operative simulation model equipped with good animation and direct interaction with the participant. In order to be a game, some objective or
standard must be met by participants. Accordingly, it is focused on helping participants to increase their understanding of problems and processes of the real system under study (Fripp, 1993, Forrester, 1995, Eden and Radford, 1990).

However, despite the previous definitions of simulation games, the definitions of this type of computer-based simulation model is not clear. Different practitioners have described this concept using different names such as gaming, simulations, business simulations and others. Within the context of this research, this term will simply be referred to as a computer based simulation game and is defined as; a traditional operative simulation model in the form of a game. In other words, this concept keeps the main characteristics of a traditional operative simulation model and uses them within a gaming environment, involving more than one participant taking part and practising the elements of competition exhibited in the business games described earlier.

This research is confined to simulation games in construction.

4.1.3 Advantages of simulation games

Due to their particular character, simulation games have special attributes which offer additional advantages to the process of learning which can positively affect their results. Senge (1990) has summarised these advantages as follows:

- Integration of the real world. This means that the simulation game is not just a tool of experimentation, but it can help represent the participant’s formed ideas about how the real system works and can help make those ideas clearer. Therefore, when participants are working on a simulation game, they are automatically substituting their real world with those assumptions exhibited in the simulation game.

- Compressing space. A simulation game makes it possible to represent the interaction between components which are often not easily visible in the real system.

- Isolation of variables. A simulation game will always be a simplification of a real situation where unimportant variables and components are excluded. As a consequence the important aspects of the system will be in focus.
• Experimental orientation. Simulation games encourage participants to actively experiment. Participants feel free from risk and external pressure to try their own ideas and to see if their assumptions can be corroborated by the results of the simulation game.

• Pauses for reflection. The execution of a simulation game can be stopped by a participant whenever they wish to have time for reflection. This reflection is continuous and is provoked in the simulation game by demonstrating to a participant possible consequences of different actions.

• Theory-based strategy. A simulation game provides new possibilities for participants to view theoretical considerations from another perspective.

• Institutional memory. Participants’ experiences can be reflected on and stored in the simulation games. In this way, all lessons learned by an organisation can be kept alive.

These features provide an ideal environment for learning within the construction domain, which enables the participants’ safe experimentation and interaction within a simulated real world.

The following list summarises other characteristics and advantages of simulation games mentioned in the literature:

• Simulation games are good at providing insight into the totality of a system. This might lead to improved understanding on the part of the participant about the functioning of the company and its problems (Senge and Sterman, 1992, Senge and Fulmer, 1993, Watson and Blackstone, 1989).

• They can arouse the interest and motivation of participants. This is even greater if the simulation game is realistic and is tailor-made to the issues and situations arising in real life. According to Anderson (1994), the simulation game should be built on what is already known by the participants, but at the same time it might help them to discover what they do not know.
• They promote communication and dialogue between participants. In this way the simulation game can also support team-building projects (Senge and Fulmer, 1993).

• Simulation games can make the training more effective by facilitating a participant-centred orientation rather than an instructor-oriented one as training traditional techniques do. This is mainly possible because simulation games enable participants to practice their own skills hands-on and see the possible consequences (Faria and Dickinson, 1994).

• Simulation games match fairly well the process of an individual’s learning style. It is of common agreement that engineers within the construction discipline learn best from experience. This probably is the main reason, why training techniques such as simulation games which encourage experimentation and reflection, are popular within this discipline (Taylor and Watford, 1978, and Fripp, 1993).

• The kind of competition promoted by simulation games is not of the kind encouraged by other traditional games where participants try to beat each other or try to compete against the computer. Participants are challenged to get the best possible results during simulation games, but the difference is that in this competition all participants will be the winners in the learning process where the results are not as important as the understanding of the processes and of the problems exhibited in the game (Senge and Fulmer, 1993, Faria and Dickinson, 1994).

• Simulation games can either incorporate deterministic or stochastic characteristics. In the first case the data and assumptions of the game are known in advance and are not subject to random change during the execution of the game, while in the stochastic case the data and assumptions can continuously change. According to Watson and Blackstone (1989), deterministic simulation games are particularly useful for educational purposes. Using this type of simulation game, participants can more easily relate their own actions in the simulation game to the results and they can more easily understand what the problems are.

• Oxford and Harman (1987), have found that simulation games can also enhance learning by increasing the amount of time that participants spend on the learning task.
Most of these characteristics describe the effects of simulation games on an individual's learning process. Although considerable advantages of using simulation games as a facilitator and support tool in training have been widely documented, there is no concrete evidence that the simulation games are superior or more effective than other techniques used in training. Fripp (1993) indicated that simulation games are at least as good, and in many cases better than other methods. Fripp (1993) found in a survey in 1991 of 150 managers of companies in the UK that even though simulation games can be time consuming and expensive, 90 per cent of the users considered they were good value for money. Ahluwalia and Haiao (1993) have also found that simulation training, when combined with conventional training, can reduce total training time by 30% to 50%.

Part of the study in Chapter 5, investigates whether the MERIT2 (section 4.4) simulation game effectively demonstrates the features of simulation games addressed in this section.

4.1.4 Disadvantages of simulation games

The use of simulation games in industrial training has some particular disadvantages. The most important of these can be summarised as follows:

- When it comes to computer-based support at work with simulation games, there is a risk that the focus will be put on technological aspects of the simulation game and not on the main educational purposes. If the simulation game is too easy, the participants might not make any extra effort in order to understand the issues which are demonstrated in the simulation game. If the game is too complex the participants will not be able to logically explain the consequences of actions in the simulation game (Fripp, 1993, Goldstein, 1992).

- The demands in skills and practical experience on the developers of simulation games is quite high considering that the simulation game should not only exhibit validated proofs of behaviour, but also compare realistically to the real system under study (Forrester, 1995, Stahl, 1988, Raush, 1995).
• The training of participants using simulation games can be time-consuming. This will increase other training costs as a consequence and make the training project less cost effective (Watson and Blackstone, 1989, Senge, 1990).

• To make easy-to-operate simulation games for non-computer literate participants can be difficult (Stahl, 1988).

• If a simulation game is not properly designed, there is a risk that it will not produce the desired learning effects. Participants could concentrate on trial-and-error experiments rather than focusing on the exploration and understanding of the simulation game, (Fripp, 1993, Watson and Blackstone, 1989).

• The results produced by the simulation games rarely correspond to mathematical calculations. Moreover, the connection between the training results and other concrete estimations in real-world production, can hardly be proved on most of the cases. According to Anderson (1994), probably the only indicators are the trainer's observations or the participants comments.

• Klein and Fleck (1990) have found that the time spent by the participants learning to play the simulation game can be a disadvantage for the company. This time, could be used in the execution of other more effective training activities.

Lansley (1989) highlighted the difficulties and problems that may face educators when using simulation games. These include:

• Unexpected administrative duties.

• The cost of setting up from scratch.

• The occasional inexplicable output from a simulation game that can undermine student's confidence in the activity.

• Familiarising students with how the simulation game works at a technical level

The fact that interpersonal issues pose a problem is of interest. The group based nature of the decision-making process offers a rich learning opportunity for the development of student's interpersonal skills or ability to work in a group. If it is regarded as a problem and not a learning opportunity, valuable insights for students about their behaviour in groups may be lost. Despite the problems listed above, educators claim that simulation games can provide learners with an exciting, engaging and fruitful
educational experience. The following section describes the role of simulation games in facilitating the learning process, and how they can help develop strategies that are important for learners within the construction domain.

4.2 SIMULATION GAMES AND THE LEARNING PROCESS

Section 2.3.1 addressed Simulation Games as a source of promoting the experiential learning process. One such example is illustrated by Armitage (1993), who adopted Kolb’s and Binsted’s model (Figure 2.5). Armitage showed how simulation games portray learning as an ongoing cyclic process, involving participants in receiving input, being involved in an experience, reflecting upon the experience, adjusting their existing cognitive maps of the world and changing the way that they take action or make decisions in the future. Armitage produced a model shown in Figure 4.2 which is a synthesis of the Kolb’s and Binsted learning cycles and gives an indication of the nature of such synthesis. It provides a way of conceptualising what is happening to participants when engaged in a simulation game and can be used to facilitate planning a learning event which makes use of a simulation game.

According to Armitage, ‘input’ is usually of theory received by a participant from the educator before the simulation game begins, and possibly throughout the simulation game. Decision Making involves participants in using theory from the input stages to inform their first decision-making process and thereafter a mixture of both input and ideas gained from reflection on feedback. Decisions are entered into the simulation game and participants receive Feedback in the form of the results sheets which gives details of the effect of decisions. Reflection and Theorising in the stage, where participants link their decisions and subsequent results with their understanding of the theory. This leads to better understanding of the theory and how it works in practice. It is also illustrates the point where discussion of the affective part of the experience can take place explicitly, encouraging students to reflect on both personal feelings and group processes. This reflection then feeds into the next decision making process. The cycle of decision making-feedback-reflection and theorising should happen a number of times during the course of a simulation game. Output occurs once the simulation game has ended.
To reinforce the act of learning (see chapter 2, the behavioural theory), learning may need to be framed in terms of an essay or a presentation of a report. This corresponds to Binstend's model, where students output what they think or know already to form a part of the input process. It may be useful for an individual's learning if this were to occur whether accreditation were necessary or not, as it may assist the participants in their reflection upon the experience, and making further links between theory and practice. One of the immediate conclusions that can be drawn from Armitage's theory, is that simulation games are suitable tools for facilitating the 'convergent learning strategies' associated with abilities of forming abstract concepts and applying them to a real situation.

The learning process through simulation games has also been illustrated by Fripp (1993) guided by the four phases of Kolb's experiential learning theory, as shown in Figure 4.3. The scale to the left illustrates the stages in the experimentation with a simulation game, and the one on the right illustrate the stages of Kolb's experiential learning model. This figure also illustrates that, each experiment can be a unique opportunity for participants to experience the consequences of their action in the simulation game and to reflect upon the results. Fripp (1993) explained that 'simulation games obviously cannot offer real experience, but they do offer the next best thing: 'on the job' learning experience, in which most participants become fully involved'. This issue is also addressed by Thatcher and Robinson (1990), who stated; 'It is relevant to use simulation games in training since they promote a type of "controlled" experience from which learning can be generated if the whole experience is used effectively'.

However, there are three additional aspects that cannot be seen in Figure 4.3, which successfully complete the whole description of the learning process supported by simulation games. These are, the 'aha effect' in the process of participant interaction.
DESIGN ISSUES

Input
(Reception of Input-Binsted)

Decision Making
(Action - Binsted, AE-Kolb)

(Simulation runs)

Output

Feedback
(Feedback-Binsted CE-Kolb)

Reflection & Theorising
(Reflection-Binsted RO & AC-Kolb)

Figure 4.2 Framework for using simulations games
(source, Armitage 1993)

Figure 4.3 The learning process through simulation games
(source, Fripp 1993)
with the simulation game. The second aspect is the process of change in the **participant’s mental models** as a consequence of a new awareness of problems demonstrated in the simulation game. The third aspect is the process of progression (see section 2.3.2).

The ‘aha-effect’ is experienced by the participant as soon as the behaviour of the simulation game or its results do not correspond to his/her expectations. Many psychologists consider this to be probably the first step of an individual’s learning process (Shirts, 1992 and Bower, 1992). Therefore, it can be emphasised that simulation games are facilitators of ‘aha-effects’ and that the number of these effects during the experimentation process with a simulation game will produce direct effects on the effectiveness of the participant’s learning process.

The process of change in **mental models**, however, occurs during the participant’s experimentation with the simulation game. If as a consequence of this a participant modifies his assumptions and understands better an issue demonstrated in the simulation game and consequently becomes better able to explain that issue, then it may be justified that a participant has improved his mental models. According to Shirts (1992), an important point concerning the decision making process is that judgement appears to improve with experience. Such concepts also support elements of deep approaches to learning described in Chapter 2.

Dewey’s model (section 2.3.2) caters for the process of **progression** as a result of the cyclic learning process. According to Dewey, for learning to occur, there must be a desire or an impulse. The learning process is therefore cyclic starting with observation, knowledge then judgement. The repetitive nature of decision making within a simulation game and the generated outcome prepares the participants for another learning cycle on the basis of previous judgement. Such progression of the learning cycle ends when a purpose is reached. Such purpose is decided by the ‘game controller’, who decides on the number of rounds the simulation game is played, or if the desired outcome is not reached, then participants may choose to participate in the simulation game when the opportunity occurs again. If such an opportunity occurs and
the participants do not take part, then either their purpose of learning is achieved or they have no desire to learn, i.e., participants been de-motivated. If participants show the desire in participating again, then there is further purpose or outcome to be achieved. These principles are discussed in chapter 5, as a result of evaluating the MERIT2 simulation game.

In order to make learning processes possible, dialogue and discussion between participants is absolutely necessary. This is the only means through which participants may be able to share their experiences, results and thoughts in the simulation game and help them to develop shared mental models of those problems demonstrated in the simulation game. Dialogue and discussion will facilitate the process of consensus between participants and will affect the speed of transferring knowledge and skills from simulation games into the real system (Elgood, 1990). This is another factor that should be recorded when evaluating the effectiveness of simulation games.

The Piagetian theory (section 2.3.2), also supports simulation and gaming in facilitating the learning process. This shows that a simulation game assists with the process of assimilation. This can occur when participants integrate new information into their existing cognitive structure (these are participants who have no background knowledge of the subject). It also assists the participants with the accommodation process in two ways (this applies to participants who have background information about the subject). Firstly, by helping to adjust or modify their cognitive structure in order to integrate the new information into it. Second by facilitating participant intuitive approaches to learning on a higher level of thinking. This is achieved by allowing the participant to interact with the simulation game through the decision making process and reflecting on such decision, the social interaction with other members of the team or with the simulation game controller and revealing the inaccuracy of ideas, also by allowing the participants to interact in a similar situation and facilitating new ways of thinking (Chapter 5).

According to the behavioural theory, a simulation game is a stimulus (which brings out the act of learning) through the decision making process, and the response is the feedback generated by the simulation each time a set of decisions has been made, this
is referred to as ‘intrinsic feedback’ (Chapter 2). Allowing the participants to apply theories and concepts formed in a new situation (whether in the game or in a real life situation) is considered as reinforcement.

Tonks and Armitage (1997), investigated the learning styles of three groups of students from different countries and analysed their feedback, after participating in a management simulation game. Tonks and Armitage identified three learning styles within these groups, and found that the feedback from these groups illustrated both deep, and surface approach to learning. Tonk and Armitage stated ‘If learning from a simulation game is taking place at a deep level, the participants should demonstrate an understanding of the theory or technique that is being demonstrated by the simulation game and an awareness of wider issues beyond the simulation. If learning from a simulation game is taking place at a surface-level, the student would demonstrate an understanding of the specific case of that simulation game, but not from it to wider issues or underlying theories’.

The factors highlighted in this section, describing how simulation games facilitate experiential learning, and the cognitive and behavioural implications, will be used as measures for investigating the effectiveness of MERIT2 simulation game in Chapter 5.

4.3 APPLICATION AREAS OF SIMULATION GAMES

Computer-based simulation games have already been used for more than a decade in education and industrial training. The areas of application include not only their regular use in academic establishments as teaching tools, but also in all types of business areas such as marketing, financing or production. In 1989 it was estimated that in the USA alone, 5000 companies were using some type of business games in industrial training development programs (Faria, 1989).

The use of simulation games in industrial training has covered a relatively wide spectrum of different simulation games. Some of the most common goals mentioned in these simulation games include:

- Increased motivation of participants and training effectiveness
• Human resource development
• To increase personal communication skills, shared responsibility and increase self awareness
• To train participants in the execution of a real job
• To provide managers with better control over their own duties and help them to understand a wide variety of circumstances
• To promote the systemic thinking and learning of participants
• To facilitate team-work between managers at companies


The following sections, briefly describe some commercially available simulation games, for the construction industry.

4.3.1 Commercially available construction games

In the construction discipline a number of games have been developed over the years. Example of such games include:

• the "Baily Simulation game" (Cooper, 1994), which provides: experience of the nature of a construction company, the role of company directors, and the tasks involved in submitting a tender by a team of engineers such as the creation of drawings, specifications, cost estimates, scale models and other appropriate documents for presentation to the client. It also illustrates aspects of human relations involved in awarding a tender;

• "Baumark I and II" (Seeling, 1994), simulates different stages with a construction company, and demonstrates the effect of different types and sizes of contracts to be undertaken by a company. It enables players to undertake project bidding and tendering and forces them to study their action in relation to the market, giving them an opportunity to explore the behaviour of a market and its potential instability;

• PYRAMID and PYRAMID II (1994), emphasise the importance of group work in undertaking time / cost planning and allows participants to experience the problems of working in a group, delegating and co-ordinating a construction project. The Pyramid game was described as a short, fun exercise with general management
applications, and "an ideal ice breaker for training courses" which makes the game suitable as a first introduction to planning and team work at a beginners level.

- "CONSTRUCTO" (Halpin, 1976), was first utilised in 1973 in construction management programs in Australia, Canada, and at several universities in the United States. CONSTRUCTO was developed to model a wide variety of construction management decisions at the site management level. At that time the simulation game was considered as being the first step in the direction of realising the potential of simulation and gaming as tools in construction management education. It is a project oriented game, which has been developed to give students the opportunity to develop their own problem response model, by confronting them with simulated situations described in terms of environmental and economical parameters and placing them in the position of being in charge of a construction project facing similar difficulties to real-world managers. The simulation game was also described as being an excellent vehicle for introducing the student to the dynamic process of planning, scheduling, and controlling projects.

Due to the similarities between the CONSTRUCTO program output and the cost and labour control reports used by "real-world" companies, the participant is immediately introduced to the concepts of comparing actual progress with the estimate. The comparison of actual and estimated progress and cost data emphasises the concept of "management by exception" in which attention is directed to those activities and cost centres that deviate from the norm. Halpin (1976), summarises his game CONSTUCTO by describing it as a realistic framework upon which many levels of sophistication can be superimposed which allows the construction management student literally to "get mud on their boots without leaving the class room".

- "AROUSAL" (A Real Organisation Unit Simulated As Life) (Lansley, 1982) has been designed to simulate the world of the directors of a medium sized enterprise. Participants in the simulation, form into small teams and take the role of the directors of that enterprise. The game assists in the development of managers and in evaluating the potential costs and benefits of different business and organisational strategies. This game has been used by a number of firms in the UK and the USA and has proved to be a valuable part of their training programme.
- "Venture" (Elgood, 1994), was designed as a form of business simulation and a management game that tests strategic perceptions rather than the participants' skills in running a production line, in a tightly defined market.
- "Conglomerate" (Elgood, 1999), designed for interactive play over the Internet, where six teams (each team consists of four-six people) are faced with managing a virtual multi-national company, which manufactures a mix of products. Each game is made up of eight turns and takes over eight-week period in real time, but equates to two years within the game. Competitors have to consider all economical and environmental data, and face dilemmas such as what to do in the face of falling share prices, and making the wrong decisions. This game is still through a trial stage.

4.3.2 Bidding Simulation games
Although there are a number of management and construction simulation games available, there is little reported on the use of bidding simulations games in training. Some approaches have attempted to model the way bidders vary their strategies as a result of significant variable characteristics of the contract. If reliable models can be deduced, a bidder can investigate minor variations in his strategies by simulating the effect of these changes over a period of time. This approach is more concerned with allowing management to explore the consequences of its action than the basic approach which concentrates on providing an optimum bid value for a given contract (Lilley, 1978). The rest of this section describes some bidding games from literature.

- "Super Bid" (AbouRizk, 1993) is a project oriented management bidding game developed to assist in training estimators in developing bidding strategies in construction. Super Bid, teaches the players about various factors to be considered during bidding, to enable the players to observe and experience what is involved in the bidding process such as, basic estimating and costing skills, forecasting, financial planning, studying the market and competition trends, decision making under uncertainty, random factors and phenomena such as providing a medium for experimenting with different bidding strategies to achieve a desired objective, and
basic financial book-keeping fundamentals (which are required to insure that players succeed in the game);

- Tam and Chan (1995), developed a simulation game on bidding and running a construction firm. The aim of the game is to confront students with simulated real world problems which they critically appraise and analyse. They must then design appropriate solutions both individually and in groups. The following areas are covered by the game:

  - practising bidding strategy;
  - comprehending market conditions in terms of the supply of works and competition;
  - appreciating the risk elements in the real world;
  - understanding the financial implications in providing continuity of work for project staff;
  - selecting the appropriate marketing strategy; and
  - arousing learning/teaching interests by the use of computer games.

This simulation game requires interaction through a network of computers between groups of participants and a supervisor. Participants can record companies' human resources, cash flow and projects on hand in data base format. Finally, the performance of each group is measured by the total return on the total asset at the end of the game. Section 4.3.3 comments on the revaluation results of this simulation game.

- MERIT2 (Harris and McCaffer, 1995, Ahmed and Thorpe et al, 1996) is a simulation game that was developed to demonstrate to the players the interacting nature of variables which need to be considered in the tendering and production phases of a construction project. The MERIT 2 simulation game has been running for the last 10 years, in industry and in higher education. It was developed in Loughborough University for Balfour Beatty and been played by at least 15,000 participants (see section 4.4).
4.3.3 Case studies.

Literature shows a few studies that have considered the effectiveness of simulation games, and measures of the effectiveness of such tools are mainly qualitative rather than quantitative.

For example Lansley (1987) produced a report on the effectiveness of AROUSAL. The report described AROUSAL as a system that provided managers with both, an understanding of critical issues that are of importance to organisational performance and the means of handling them at strategic and operational levels. The research of the effectiveness of AROUSAL revealed that;

Construction managers and professionals had little if any difficulties in:
- utilising knowledge acquired from other components of management education progress or from their experience;
- achieving a high degree of involvement in simulation exercise;
- accepting the context of the firm and its behaviour; and
- recognising their decision-making processes with the computer simulated business activities.

The report also stated that, the system has achieved a high degree of acceptance by industry. Some of the major features which have contributed to this level of acceptance reflect the philosophy underlying the system, and include the following views and beliefs strongly held by industry:
- that managers learn by doing,
- that the cost effective learning takes place when managers are able to introduce and experiment with new ideas and techniques against the background of familiar organisational settings which are of importance to them;
- that the effectiveness is best measured by quantifiable results;
- that effective managers are able to forecast the results of their actions, and take specific action to effect control; and
- that effective managers need to integrate a wide range of skills and operate the full range of decision levels.
Another example is produced by Tam and Chan (1995), the results of a questionnaire survey undertaken to detect the student's opinion upon different aspects of their simulation game. Their approach however, does not show the effectiveness of the simulation game, and provoke the need for in-depth approaches to determine the true effectiveness of these tools.

MERIT2 illustrates another example, of a computer based simulation game, which has been successfully running over the last ten years, but no measures of its effectiveness have been undertaken. It is therefore proposed by this study, to investigate the effectiveness of the MERIT2 simulation game, adopting the proposed strategies produced by the framework developed in Chapter 3. Therefore, to aid this investigation, section 4.4 describes MERIT2 in detail.

4.4 MERIT2

MERIT 2 (Managing Engineering Resources Involves Team Work). It is a construction management simulation game which allows up to 1000 teams referred to as companies to operate a construction company for up to 16 periods or quarters, representing 4 trading years. The participants are required to control and manage the direction of their company through inter-related marketing, tendering, overhead allocation, labour and staffing and general financial decisions. The companies operate in a computer-simulated market based on current UK statistics. The game is arranged so that it can be played by 3-6 participants in each team of players, where each team represents a company identified by a unique name.

The simulation game was created for Balfour Beatty Construction Limited in 1989. Since 1992 "MERIT 2" has run annually via the Institution of Civil Engineers. The leading teams are invited to play the final at Loughborough. So far, about 15,000 participants have played MERIT over the last 10 years. To provide a defined description of the implementation and the structure of MERIT2, the approach introduced by the logical steps proposed by the framework developed in Chapter 3 is adopted. The parties involved at different stages of the MERIT2 are described below.
• The creation of MERIT2 was initiated by Balfour Beatty construction in support of the ICE (Institution of Civil Engineers). The company, provided support for the development of the computer based simulation game by making realistic company data available;

• The Department of Civil and Building Engineering were the ‘project leaders’, taking the responsibility of monitoring the project inputs and ensuring that the required outputs are made available;

• A System analyst, took the role of analysing the real system (supported by the data made available by the company), building a computer-based model and analysing the results demanded, which require a wide range of skills from the project leader; and

• A computer specialist acted as a programmer.

MERIT2 was developed to serve the needs of graduate civil engineers preparing for chartership and for students undertaking their postgraduate and undergraduate degree in construction related disciplines.

4.4.1 Pre-implementation stage

This section provides a review of the plans for implementing MERIT2.

i. Aims and objectives of MERIT2

The creation of this simulation game was related to Balfour Beatty’s needs for a training tool to assist with:

• The development of their employees professional skills, particularly for graduates who are in need for CPD;

• Improving the quality of human resources employed within the company;

• Increasing the employees motivation and their training effectiveness.

However, within the area of construction management, the company’s goals are:

• To create an environment that allows participants experience the decision making process of inter-related nature for various functions involved in managing construction companies.
• To develop mental and communication skills, through grasping the facts given and problem solving at different stages of the simulation game;
• To develop the participants’ team working and team building skills and sharpen the leadership skills of engineers;
• To develop social and communication skills;
• To serve as a management-training tool for engineers in the functional areas that often do not form a part of their academic training;
• To encourage greater interpersonal skills for engineering managers, by raising the participants’ self-awareness, strength and limitation within the simulated environment.

To meet such needs and goals, it was therefore proposed that MERIT2 would be developed to give participants the experience of dealing with:

• Problem of constantly revising targets and plans;
• Problem of allowing for overheads where workload differs from the forecast;
• Problem of cash retains on growth;
• Problem of overhead commitments when trying to reduce the size of the company;
• Bidding situation where the actions and estimates of other companies thwart your own plans;
• Pressure of reducing mark-up when insufficient number of contracts are being won;
• Problems of allocating, recruiting, and laying off human resources (Project Managers and labour).

ii. Targeted users
MERIT2 was planned to be used as:

a. A training tool in the construction industry
Balfour Beatty envisaged that motivated participants would be those who are:
• Reaching a required standard set by their company;
• Gaining training experience in company decisions and construction management;
• Qualify for chartership.
It was also planned that the creation of such simulation game would motivate its participants by,

- Meeting their needs to improve their individual learning or organisational learning.
- Meeting the training needs for certain ages and specific background.
- Making it of competitive nature with a reward for success.
- Making it an alternative tool for training, which allows participants to take part out of choice or interest.
- Making the background information available and easily accessed and a smooth flow of information when the game is in process.

b. An educational tool for undergraduate and postgraduate students

One of the initial objectives of MERIT2 in the Department of Civil Engineering was to allow the participants to learn about the usefulness of certain concepts raised by the simulation game and allowing them to learn by experimenting these concepts in a realistic but safe environment. For undergraduates and postgraduates with little or no practical experience, the simulation game was planned to provide them with a chance to learn about the limitations of theoretical models and some of the practicalities of implementation, so that their appreciation of the relevance and application of models is more firmly rooted.

iii. Targeted strategies

MERIT2 was planned to develop the following skills:

- Decision making skills;
- Team working and team-building skills, i.e., the ability to create, work as part of, or manage a team;
- Planning skills;
- Social and communication skills, i.e., exchanging ideas and sharing the learning experience with other members of the team;
- Leadership skills;
- Creativity skills, i.e., the attitude and ability to find new and better ways of doing things,
• Mental and intellectual skills, i.e., to deal with information, assimilate facts and inferences and solve problems;
• Ability to deal with change, i.e., flexibility and adaptability in the face of an ever changing world;
• Knowing the big picture, i.e., vision, awareness of the strategy of the organisation and how it is derived;
• Self awareness.

The simulation game also aims at improving the participants knowledge of basic facts about the construction companies. In addition it simulates the participants’ knowledge of:
• Bidding for jobs;
• Human resource allocation;
• Financial resource allocation.

It was also planned that the outcomes from participating in MERIT2 will generate knowledge of the following areas:
• Organisation theory;
• Planning;
• Forecasting;
• Financial management;
• Marketing;
• Group behaviour;
• Competitive bidding.

Chapter 5, investigates the effectiveness of MERIT2 in meeting these strategies.

4.4.2 The development and implementation stage

a. The structure of MERIT2

"MERIT 2" was developed to allow participants to operate a construction company for up to sixteen periods or quarters representing four trading years from a historically established position of one year. The frequency of the decision periods is restricted by
the computer turn rounds and the time needed by the players between decisions for analysis. Operating at two periods per week, the simulation game can be played within eight weeks, but much faster rates of play have been achieved, with four decision periods per day being the maximum.

The simulation game operates in two modes:

- a postal mode whereby up to 1000 participating companies compete for a number of specified periods not with each other but against a computer simulation;
- a competitive mode where at the end of the postal mode, the leading companies compete in a final against each other for further specified number of periods. This competition is for jobs and available project managers, while continuing to manage the company operations.

The environment in the simulation game involves several competing companies and participants playing the role of estimators and managers responsible for pricing bids, allocating labour, engaging the companies financial position etc.. The objective is to achieve the highest performance indicators score, and the winner of the competitive phase is deemed the overall winner.

b. Operation of MERIT2

Stage 1: The introduction and briefing to MERIT2

All participants are provided with the following information before taking part in MERIT2:

- A briefing manual which introduces and describes "MERIT 2" and how it is played. It also gives an introduction to the overall aims and objectives of the simulation game, and an overview of the principles concepts that have to be addressed. It refers to the specific simulation game parameters for measuring the performance and a short description of the market,
- Company reports which describe the immediate past history of one year comprising on-going job reports and data for quarters -4 to -1;
- A list of available Project Managers and their CV's as provided by the staff Recruitment Agency,
- A print out of a list of the current jobs which are available for tender.
- Decision forms for submitting bids; labour allocation; project managers allocation, overhead allocation and cash distribution (this may also be submitted on diskette, software being provided for this).

Participants must complete their decisions and return them to the game controller (supervisor), who processes these decisions.

**Tasks**

The participants are expected to study the manual and, before filling in the decision forms in order to develop an understanding of the simulation game. All decisions made by the acting companies (participants) are handed over to the game controller (supervisor), to be processed and the results returned back to each company with a set of reports containing decision sheets for the next quarter.

The key decisions required from the competitors each quarter are:

- Selection of the sectors of the market in which to apply marketing effort;
- Control of the company overheads, in marketing, estimating, measurement and general Head Office Costs;
- Choice of tenders to be submitted together with mark-up and site on-costs required;
- For each contract awarded, allocation of Project Manager, and choice between direct labour and sub-contractors;
- For each current contract, management of the labour force and site staff;
- For the company, control of cash flow, operating profit, and other key operating factors;
- Use of cash to reduce debt burden, increase the capital base, and shareholders dividend;
- Increase of capital borrowing and decision on liquidating assets.
Stage 2: Feedback and reflection

After the results have been processed the feedback generated from the computer simulation is returned to the participants. They receive a set of reports and the company decision sheets for the next period, and a report of their progress to date. The computer simulation is also updated and ready for the new set of decisions.

- **Generated reports:** After processing the decisions made at each quarter, the following reports are generated by the computer simulation on the jobs being undertaken by the company and are distributed by the game controller:

- **Job bids and jobs won report:** This report gives details of the bids submitted by the company in the last quarter, and whether the company won any contracts. If the client believes that the company is unlikely to complete the contract and doubts the company's financial standing, even though their tender is the lowest, the client may not award the contract. This will be reported as the "client not prepared to award tender column".

Each contract won is controlled by an on-going job report, which gives the current position on:
- planned costs-as estimated;
- planned value-as estimated;
- planned labour-as estimated;
- actual labour-total labour allocated;
- expected cost-calculated on a pro rata basis of actual labour, adjusted for the training of the new recruits and depending on the expenditure of the head office overheads;
- total costs from-actual costs, additional costs and penalty clauses costs;
- actual value-estimated cost plus mark up depending on the quality of the project manager and the distance between the site and head office;
- measured value-depending on the level of expenditure with respect to turnover of the measurement effort element of the overhead;
- gross profit-difference between measured value and total actual costs.
• percentage completed—measured by achieved actual value (not measured value) as a proportion of planned value;
• remaining value to complete—total planned value less the actual value to date

Additionally the following reports are available to control and monitor the company's performance:

• Aggregate cost-value reports—giving costs, value and gross profit from all operating contracts and the gross profit less the company overheads;
• Company cash report—which presents the cash calculations on a quarter by quarter basis;
• Company job status report—giving the cumulative profit less overheads and the company cash flow;
• Company overhead report—giving the cost of the individual overheads and the total overhead period by period (quarter by quarter basis);
• Company profit report—for each year giving the profit net interest charges each year;
• Company turnover report—giving the turnover for the company year by year;
• Forward work report—giving the forward work load for the quarters to come (planned value and planned cost for all jobs which extend beyond the current quarter);
• Performance Indicators report—this reflects the results of the decision making process as measured against a set of performance indicators.

Performance indicators

The objective of the decision making process is to achieve the highest performance indicators score. The weightings of each of the factors is given in the game parameters before starting and are listed as shown on the next page:
Each of these indicators are compared with the position at the beginning of the simulation game, and expressed as the change to a start figure, given relative weighting to other indicators. This is taken as the definitive performance indicator.

**Stage 3: Final report**

Stage 2 is repeated until the game controller decides on the last quarter or period. The simulation game at stage 3 will come to an end and the last set of decisions be processed and the final reports and performance indicators generated.

Figure 4.4 illustrates the phases of operation of MERIT 2.

### 4.5 SUMMARY AND GUIDE TO THE NEXT CHAPTER

This chapter described the history and development of simulation games and distinguished between the terms of games, role play, exercise and simulation games, providing a clear definition of computer based simulation games. The latter is the focus of this study.

The advantages and disadvantages of computer based simulation games were reviewed from literature, and their role in facilitating experiential learning described, justifying their wide spread use and applications for engineering education, particularly in construction. However, few case studies describing the effectiveness of simulation
Figure 4.4 Stages of operation of the MERIT 2 simulation game
games exist. Even when such studies are carried out, qualitative rather than quantitative measures of the effectiveness of these tools are reported, which are mainly dependent on the educators’ observations and/or the participants’ comments.

Therefore, to promote a study that carries quantitative measures of the effectiveness of these tools, this study provided a detailed description of the MERIT2 computer based simulation games. MERIT2 has been running over ten years, and its measures of success is often demonstrated by the number of participants who took part in the simulation game, in academia and industry.

Chapter 5 carries out an investigation into the effectiveness of the MERIT2 simulation game, by surveying the previous participants’ opinion. However, to aid this investigation, a number of objective measures of the effectiveness of MERIT2 as a CAL tool to aid the learning process in construction management must be set. Such measures are derived from the study of effective learning in Chapter 2 and the strategic framework developed in Chapter 3. This suggests that, MERIT2 is an effective tool if it successfully:

1. **Achieves the aims and objectives it was originally created for**
   This is investigated in chapter 5, by surveying two samples of participants; those who took part in MERIT2 to promote their Continuous Professional Development and; those took part in MERIT2 as part of their academic requirements. Analysing participants’ opinion upon various aspects of the simulation game, will help determine if MERIT2 meets its objectives as a training tool in the construction industry, and as an educational tool to support the traditional methods of learning in construction management.

2. **Proves motivating**
   As indicated by the literature surveyed in previous chapters, motivation is a measure of effective learning, but it is hard to detect. Chapter 5 investigates other measures studied from literature such as, enjoyment and interest to take part in MERIT2 again.
3. Promotes the targeted learning strategies to facilitate ‘off the job’ learning

This can be investigated monitoring the cyclic stages of running MERIT2, and analysis of participants’ responses and comments upon each stage. This will also help assess how the effectiveness of one stage can affect other stages and hence, different learning and cognitive strategies. These steps are guided by Figure 4.2 (Armitage’s framework) and Figure 4.3 (Fripp’s explanation of the learning process through simulation).

4. Meets the participants’ educational needs

This can be investigated by correlating the participants’ opinion to their background, and whether MERIT2 catered for individuals’ needs or its targeted users.

Literature surveyed in previous chapters also indicates that there is a number of factors that indirectly influence these measures, such as;

**Participants**

- Participants’ educational needs and background, influences their enjoyment, interest and motivation to take part in the simulation game.
- Participants’ background influences the level of knowledge improvement that can be obtained from taking part in the simulation game.
- Participants’ background influences their value of the simulation game.
- Participants’ background influences their opinion of the relevance of the game.
- Participants’ background influences their understanding of the background information before taking part in the simulation game.

**The operation of MERIT2**

- The operation of the simulation game influences the participants’ performance.
- The quality of the background information given before interacting with the simulation game influences the participants’ performance.

**The structure of MERIT2**

The simulation game is considered to be effectively structured if:

- It is enjoyable and motivating independent of the participants’ background
• It provides intrinsic feedback which is closely tied to the original aims and objectives of the simulation game, and hence, enhances participants’ motivation and curiosity to learn more.

• It promotes a high level of cognitive development and a deep approach to learning.

• It effectively exercises its capability of promoting experiential learning, allowing for ‘reflection’, and reinforcement of learning.

• It promotes the required learning strategies.

The methodology adopted in Chapter 5, aims at differentiating between the effectiveness of MERIT2 as a CAL tool and whether such effectiveness is independent of the participants’ performance and background. To aid this investigation, both summative and formative evaluations were carried out (these are discussed in section 3.3.3).
CHAPTER FIVE
EVALUATION OF MERIT2

5.1 INTRODUCTION

5.2 SURVEYED SAMPLE 1: MERIT2 AS A TRAINING TOOL
   5.2.1 Analysis of attributes (participants’ background and details)
   5.2.2 Analysis of responses
   5.2.3 Response interdependency
   5.2.4 Summary of results
   5.2.5 Discussion of results and conclusions

5.3 SURVEYED SAMPLE 2: MERIT2 AS AN EDUCATIONAL TOOL
   5.3.1 Participants’ opinion of MERIT2
   5.3.2 Knowledge testing
   5.3.3 Confidence development survey
   5.3.4 Main findings

5.4 CONCLUSIONS
CHAPTER 5

EVALUATION OF MERIT2

5.1 INTRODUCTION
The main aim of this chapter is to investigate the effectiveness of MERIT2 as a CAL tool to promote learning in construction management, by applying qualitative and quantitative evaluation measures.

To achieve this, the following tasks were carried out:

- A postal survey was undertaken targeted at participants who work in the construction industry and took part in MERIT2 to enhance their Continuous Professional Development;
- A second survey of a group of postgraduate students preparing for masters in construction management at Loughborough University, and took part in MERIT2 as part of their academic requirement.

This chapter describes these surveys and their objectives, the methods of data collection and their analyses.

5.2 SURVEYED SAMPLE 1: MERIT2 AS A TRAINING TOOL
The aim of this survey was to investigate the effectiveness of MERIT2 as a CAL tool to promote CPD in construction management, and to identify groups of participants who benefited most from the simulation game. Accordingly, a postal survey was piloted to trace previous participants, who took part in MERIT2 in 1990-1993, to supplement their CPD while working in the construction industry. The names and addresses of these participants were provided by the ICE. A total of 600 questionnaires were posted, 236 responded forming 39% of the contacted participants. A copy of the questionnaire is enclosed in Appendix D.

The data collected from this survey were analysed using Nonparametric statistical techniques. These techniques are also called `ranking tests', and differ from parametric
tests in that, the assumptions made, or conclusions drawn are regardless of the shape of the population (s), whereas parametric tests assume that the scores are drawn from a normally distributed population (Siegel, 1956).

The data collected from the questionnaire survey investigated:

i. Participants’ background, i.e., their ages, subject of study, level of education, number of times they took part in MERIT2, types and years of experience.

ii. Efficiency of the support material and the introductory stage of MERIT, including the:
   - introduction and briefing to the simulation game,
   - quality of information given before starting the simulation game,
   - overall information given for filling in the bidding forms.

iii. The effectiveness of MERIT2 as a CAL tool to convey knowledge of areas in construction management upon making decisions on:
   - bids,
   - labour allocation,
   - project manager allocation,
   - overhead allocation,
   - cash distribution.

Improvement in participants’ knowledge of other areas of construction management as a result of participating in the simulation game were also investigated.

iv. Other measures of the effectiveness of MERIT2 are investigated by analysing participants’ responses towards;
   - enjoyment of the simulation game,
   - value of the simulation game,
   - relevance of the simulation game,
   - interest to take part in MERIT2 again.

To aid this investigation, the following statistical tests were carried out, where appropriate:

a. Analysis of Attributes. Participants’ backgrounds were grouped into categories and analysed in percentages, using the SPSS summary of frequency command. One-Way Anova test is also used to test that several independent groups come from populations with the same mean.
b. Analysis of responses. The ordinal data collected from the participants' responses to the game contained 1 to 5 categories of ranking, denoting 1 for very poor, 2 for poor, 3 for neutral, 4 for good, and 5 for very good. This shows that a continuum of poor and good region exists in the scale. Good region contains a continuum ranging from good to very good. The central region contains fair scores. In order to obtain a probability statement from the responses of the participants, the five categories of the scale were grouped into three regions: “poor”, “fair”, and “good”. The percentage of frequency in each of these regions were calculated and tabulated. In order to specifically obtain the central tendency of rating (for example poor, fair, good etc ) the mean score for each one of the variables was calculated by using the command, “custom table”, through SPSS-X (Release 3.0).

c. The \( x^2 \) one sample test. This test is performed to test the Null Hypothesis as to whether the observed frequency of scores are close to the expected frequency of score, i.e., whether participants’ responses were given at random or had definite preference of scoring.

d. Kruskal-Wallis H. Tests whether several independent samples come from the same population, i.e., to test the Null Hypothesis that the participants’ responses are dependent of their background.

e. The Pearson’s Correlation Coefficient R. This is a measure of linear association between two variables, and is used to investigate whether there is any association between participants’ responses to some aspects of the simulation game and others.

Appendix E describes these statistical tests in more detail and gives examples of the data output generated by these tests. The rest of this section provides a summary of the results generated from these enquiries.

5.2.1 Analysis of attributes (participants’ background and details)

This section describes the participants’ details and background, presented in percentages of frequencies (Table 5.1) using the SPSS summary of frequencies command. In statistical terms, these variable are referred to as ‘attributes’.

Participants were originally categorised into four age groups, these were: Group 1 (18-21), Group 2 (22-25), Group 3 (26-29) and Group 4 (30+). However, a small percentage
of participants belonged to age groups 1 and 2. Therefore to help achieve more global results, participants were categorised into two groups. Group 1 (> 25 years) formed 44.5% of the population and group 2 (< or equal to 25 years) formed 55.5% of the population. Participants were also grouped according to their level of education. The analysis of frequencies showed three groups of participants, which were BSc holders, postgraduate degree holders, and sub BSc holders. However, a small percentage of participants held postgraduate degrees and sub BSc level of education, accordingly participants were classified into two groups. Group 1 presents participants with BSc and postgraduate degrees forming 89.4% of the population and Group 2 with less than BSc level of education. The results also showed that, 89.4% of the population were Civil Engineers, and 10.6% had other subject specialities. About 65% of the population sample took part in MERIT2 once and 35% took part twice. 2.1% of the population had no experience, 71.2% worked mainly for contractors and 27.7% worked for consultants. 41.5% of the participants have more than three years of experience and 58.5% have three or less years of experience.

The results of the crosstabs $x^2$ test showed that H0 is rejected (H0: The probability that there is no interaction between the different groups of participants), for the interaction between the ages of participants and their years of experience. More than the expected number of the older age group belonged to the more experienced group of participants.

MI:RIT2 is targeted at learners aged between 22-26 years old, with a Civil Engineering background, an average of three years experience or postgraduate qualifications. It is intended to enrich the experience of those who have mainly worked for contractors. The analysis of attributes shows that this is a presentable sample which mainly consists of the MERIT2’s targeted users. Therefore, this is considered a reliable sample that reflects the targeted users’ views of the simulation game.

This is also considered a representative sample used to compare responses of:

- the targeted age group of 25 years old or less vs the older ages groups of >25 years
- those who took part once or twice in the simulation game;
- those who worked for contractors vs those who worked for consultants;
targeted participants with three or less years of experience vs the more experienced participants with more than three years of experience; This sample however, may not provide reliable evidence to compare responses of Civil Engineers vs non Civil Engineers, and those with higher degrees vs others with less than BSc level of education. This is because of the unbalanced percentages of these groups as illustrated in Table 5.1. Although comparisons will be made to report certain observations, firm conclusions cannot be drawn from the participants’ responses given by these groups.

<table>
<thead>
<tr>
<th>Background</th>
<th>Percentage of frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ages</td>
<td></td>
</tr>
<tr>
<td>&gt;25 years</td>
<td>44.5</td>
</tr>
<tr>
<td>&lt; or = 25</td>
<td>55.5</td>
</tr>
<tr>
<td>Level of education</td>
<td></td>
</tr>
<tr>
<td>B.Sc. and higher</td>
<td>89.4</td>
</tr>
<tr>
<td>B.Sc</td>
<td>10.6</td>
</tr>
<tr>
<td>Subject of study</td>
<td></td>
</tr>
<tr>
<td>Civil Eng.</td>
<td>89.4</td>
</tr>
<tr>
<td>Non Civil Eng.</td>
<td>10.6</td>
</tr>
<tr>
<td>Times participants</td>
<td></td>
</tr>
<tr>
<td>Once</td>
<td>65.7</td>
</tr>
<tr>
<td>Twice</td>
<td>34.3</td>
</tr>
<tr>
<td>Type of experience</td>
<td></td>
</tr>
<tr>
<td>no experience</td>
<td>2.1</td>
</tr>
<tr>
<td>Consultants</td>
<td>65.7</td>
</tr>
<tr>
<td>Contractors</td>
<td>71.2</td>
</tr>
<tr>
<td>Years of experience</td>
<td></td>
</tr>
<tr>
<td>&gt; 3 years</td>
<td>41.5</td>
</tr>
<tr>
<td>&lt; or = 3 years</td>
<td>58.5</td>
</tr>
</tbody>
</table>

Table 5.1: Summary of the participants’ background

5.2.2 Analysis of responses

This section provides a summary of the participants’ responses given in scores, to different aspects of the simulation game, and the analysis of these responses using the relevant statistical tests, described in section 5.2 of this chapter.
i. Participants' responses to the introductory stage of MERIT2

This section provides a summary of the data collected from participants' responses, reflecting their opinion upon aspects related to the introductory stage, as listed below:

- Introduction and briefing to the simulation game;
- Quality of information given before starting the simulation game;
- Overall information given for filling in the bidding forms.

The SPSS summary of frequencies command is used to analyse the given responses to the introductory aspects of the game. Table 5.2 shows the results of two tailed t-tests at 95% confidence level to test the Null Hypothesis that, the average scores given to the introductory stage of the game were 3 or close to 3. These results show that there is no significant difference between mean scores given by the sample population to the introductory stage of the game. Also, that the introductory stage of the game is fair, at 95% confidence level. The distribution of the frequencies of these scores shows that the highest proportion of participants fall in the 'fair' category, while less proportion fall in the 'good' region and least in the 'poor' region.

<table>
<thead>
<tr>
<th>Tested parameters</th>
<th>Response (%)</th>
<th>Scores</th>
<th>Significance 95% C.L.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poor</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>Introduction and briefing to the simulation game</td>
<td>27</td>
<td>42</td>
<td>31</td>
</tr>
<tr>
<td>Quality of information given before starting the game</td>
<td>29</td>
<td>44</td>
<td>43</td>
</tr>
<tr>
<td>Overall information given for filling in the bidding</td>
<td>23</td>
<td>43</td>
<td>33</td>
</tr>
</tbody>
</table>

Table 5.2: Percentage frequency of scorings to the introductory stage of MERIT2

To test the Null Hypothesis that these scores are given at random, a non-parametric Chi-square test is applied. Table 5.3 depicts the values of Chi-square and the associated values of significance under H0 (H0: Probability of scores given at random). The results of this test show that, for values of significance of <0.05, the probability associated with H0 is
rejected, concluding that these scores are not given at random and that participants have preferences in scoring.

<table>
<thead>
<tr>
<th>Tested parameters</th>
<th>$x^2$</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Introduction and briefing to the game</em></td>
<td>9.08</td>
<td>0.011</td>
</tr>
<tr>
<td><em>Quality of information given before starting the game</em></td>
<td>12.34</td>
<td>0.002</td>
</tr>
<tr>
<td><em>Overall information given for filling in the bidding forms</em></td>
<td>14.04</td>
<td>0.0009</td>
</tr>
</tbody>
</table>

**Table 5.3: Summary of the level of significance from the Chi-square test**

The Kruskal Wallis one way analysis of variance $H$ is used to test the Null Hypothesis that participants responses are independent of their backgrounds. Table 5.4 depicts the value of $H$ for a level of significance $<0.05$ under the null hypothesis (H0). These results indicate that the participants opinion of the ‘quality of information given in the manual’ and ‘overall information given for filling in the bidding forms’ are dependent on their ‘years of experience’. For values close to 0.05, ‘participants’ ages may also be a contributing factor. This may be due to the interaction between the two attributes, i.e., ages and years of experience mentioned in section 5.2.1.

<table>
<thead>
<tr>
<th>Participants’ background</th>
<th>Introduction and briefing to the game</th>
<th>Quality of information given in the manual</th>
<th>Information given for filling in the bidding forms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.2754</td>
<td>0.0856</td>
<td>0.0739</td>
</tr>
<tr>
<td>Level of education</td>
<td>0.8116</td>
<td>0.1976</td>
<td>0.6766</td>
</tr>
<tr>
<td>Subject of study</td>
<td>0.8116</td>
<td>0.6660</td>
<td>0.2151</td>
</tr>
<tr>
<td>Times MERIT2 played</td>
<td>0.8368</td>
<td>0.8028</td>
<td>0.76~9</td>
</tr>
<tr>
<td>Years of experience</td>
<td>0.8426</td>
<td>0.0187</td>
<td>0.0566</td>
</tr>
</tbody>
</table>

**Table 5.4: Kruskal Wallis analysis of variance, for the introductory stage of MERIT2**

For a closer examination of such group behaviour, the frequency distribution of scores given by participants with different ‘age groups’ and different ‘years of experience’, to the ‘quality of information given in the manual’ and the ‘quality of information given for
filling in the bidding forms' are summarised in Table 5.5. These results show that the older age group gave higher scores to the quality information given in the manual. Similarly, higher scores are given by the older and more experienced participants to the quality of information given for filling in the bidding forms.

It can therefore be concluded that the scores given to the introductory stage of MERIT2 by all groups of participants, fall in the fair region. However, the older or more experienced participants showed better response to the quality of information in the manual, than the younger and less experienced participants. This suggests that the level of information given at the introductory stage of MERIT2, may have been higher than the existing level of experience for the younger and the less experienced participants. Although these scores do not reflect participants' great satisfaction with the simulation game, participants’ existing knowledge is a contributing factor towards judging its effectiveness.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Backgrounds</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Groups Average scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of information given</td>
<td>Ages 25</td>
<td>23</td>
<td>51</td>
<td>31</td>
<td>3.09</td>
</tr>
<tr>
<td></td>
<td>Ages 25 or less</td>
<td>45</td>
<td>53</td>
<td>33</td>
<td>2.87</td>
</tr>
<tr>
<td></td>
<td>&gt;3 years exp.</td>
<td>35</td>
<td>43</td>
<td>20</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>3 or = years exp.</td>
<td>33</td>
<td>61</td>
<td>44</td>
<td>3.00</td>
</tr>
<tr>
<td>Overall information for filling the bidding forms</td>
<td>Ages 25</td>
<td>31</td>
<td>36</td>
<td>38</td>
<td>3.19</td>
</tr>
<tr>
<td></td>
<td>Ages 25 or less</td>
<td>32</td>
<td>40</td>
<td>59</td>
<td>3.03</td>
</tr>
<tr>
<td></td>
<td>&gt;3 years exp.</td>
<td>24</td>
<td>33</td>
<td>41</td>
<td>3.14</td>
</tr>
<tr>
<td></td>
<td>3 or = years exp.</td>
<td>39</td>
<td>43</td>
<td>56</td>
<td>3.00</td>
</tr>
</tbody>
</table>

Table 5.5: Analysis of group scorings frequencies and average scorings

ii. Knowledge improved upon filling in the bidding forms

Participants were asked to assess how their knowledge gained as a result of making decisions of:

- Bids;
- Labour allocation;
- Project managers allocation;
- Overhead allocation,
- Cash distribution borrowings.

Table 5.6 presents the participants’ responses, expressed in percentages, and the mean scores given to knowledge improvement upon the decision making process. These results reveal that mean scores of 3 are given to the knowledge improved upon decisions on bids and project managers, and a mean score of 3.2 (which is significantly higher than 3, indicated by the results of the two tailed t-test at 95% confidence level) to the labour allocation decisions. However, scores of 2.9 (not significantly less than 3) to knowledge improved upon decision on overhead allocation, and 2.7 (significantly <3 at 95% confidence level) given to the knowledge improved upon decisions made on cash distribution indicate. The results indicate ‘fair’ knowledge improvement upon decisions on bids and overhead allocation. ‘More than fair’ improvement upon decisions on labour allocation and ‘less than fair’ improvement upon decision on cash distribution and borrowings. Table 5.6, also shows the frequency distribution of these scoring, reflecting the behaviour of the sample population hence resulting these averages.

<table>
<thead>
<tr>
<th>Knowledge improved upon</th>
<th>Response (%)</th>
<th>Average scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decisions on bids</td>
<td>Poor 30</td>
<td>Fair 33</td>
</tr>
<tr>
<td>Decisions on labour allocation</td>
<td>Poor 22</td>
<td>Fair 35</td>
</tr>
<tr>
<td>Decisions on project managers</td>
<td>Poor 33</td>
<td>Fair 37</td>
</tr>
<tr>
<td>Decisions on overhead allocation</td>
<td>Poor 34</td>
<td>Fair 39</td>
</tr>
<tr>
<td>Decisions on cash distribution</td>
<td>Poor 47</td>
<td>Fair 31</td>
</tr>
</tbody>
</table>

Table 5.6: Percentage frequency of scorings to the introductory stage of MERIT2

Table 5.7 depicts the values of Chi-square and the associated values of significance under H0 (H0: Probability of scores given at random). The results of this test shows that, for values of significance of <0.05, the probability associated with H0 is rejected for decisions on labour allocation, overhead allocation and cash distribution and borrowings, indicating that these scores are not given at random. However, the probability associated with H0 for decisions on bids and project managers is accepted, indicating that these scores are given at random.
To test the Null Hypothesis that the participants' knowledge improvement upon the decision made is independent of their background, the Kruskal Wallis Analysis of Variance test was carried out and the results are presented in Table 5.8. For a level of significance of <0.05, the results indicate that decision on bids, labour allocation, project managers, and overhead allocation, are dependent on the participants subject of study. However, the analysis of attributes (summarised in Table 5.1), showed that 89.4% of the sample population are Civil Engineers and 10.6% are not. Such a difference in group size does not provide solid evidence on which to compare the responses of both groups.

<table>
<thead>
<tr>
<th>Tested parameters</th>
<th>Values of Chisquare</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decisions on bids</td>
<td>2.35</td>
<td>0.31</td>
</tr>
<tr>
<td>Decisions on labour allocation</td>
<td>15.62</td>
<td>0.0004</td>
</tr>
<tr>
<td>Decisions on project managers</td>
<td>1.9</td>
<td>0.39</td>
</tr>
<tr>
<td>Decisions on overhead allocation</td>
<td>5.75</td>
<td>0.056</td>
</tr>
<tr>
<td>Decisions on cash distribution</td>
<td>20.78</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 5.7: Chi-square test values and levels of significance of scores given to knowledge improved upon the decisions made for filling the bidding forms

<table>
<thead>
<tr>
<th>Decisions vs. background</th>
<th>Decisions on bids</th>
<th>Decisions on labour allocation</th>
<th>Decisions on project manager allocation</th>
<th>Decisions on overhead allocation</th>
<th>Decisions on cash distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.9366</td>
<td>0.1375</td>
<td>0.8353</td>
<td>0.4643</td>
<td>0.9884</td>
</tr>
<tr>
<td>Level of Education</td>
<td>0.1186</td>
<td>0.7119</td>
<td>0.6676</td>
<td>0.4457</td>
<td>0.3255</td>
</tr>
<tr>
<td>Subject of study</td>
<td>0.0046</td>
<td>0.0029</td>
<td>0.0260</td>
<td>0.0509</td>
<td>0.3864</td>
</tr>
<tr>
<td>Times the simulation game played</td>
<td>0.2864</td>
<td>0.5936</td>
<td>0.8805</td>
<td>0.7670</td>
<td>0.8914</td>
</tr>
<tr>
<td>Years of experience</td>
<td>0.7758</td>
<td>0.8225</td>
<td>0.9410</td>
<td>0.6200</td>
<td>0.6716</td>
</tr>
</tbody>
</table>

Table 5.8: Analysis of variance, for decisions made for filling in the bidding forms
Table 5.9 shows the groups behaviour by illustrating the distribution of frequency of scores given by these groups together with the average scores. These results show that participants with civil engineering qualifications gave higher scores to knowledge improvement upon the decision making process, than participants with non civil engineering qualification. The discrepancy in scores between the two groups are noticeably large for decision on bids and labour allocation. The average scores given by the civil engineering participants fall in the fair region, while those given by the non civil engineers fall in the poor region. The discrepancy between these responses, becomes smaller for knowledge improved upon overhead allocation and decision on cash distribution and borrowings where, while civil engineers show more improvement in knowledge, the scores given by both groups fall in the poor region.

<table>
<thead>
<tr>
<th>Decisions on study</th>
<th>Subject of study</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Group averages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bids</td>
<td>Non Civil Eng.</td>
<td>13</td>
<td>8</td>
<td>4</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td>Civil Eng.</td>
<td>57</td>
<td>69</td>
<td>85</td>
<td>3.1</td>
</tr>
<tr>
<td>Labour allocation</td>
<td>Non Civil Eng.</td>
<td>11</td>
<td>9</td>
<td>5</td>
<td>2.36</td>
</tr>
<tr>
<td></td>
<td>Civil Eng.</td>
<td>41</td>
<td>74</td>
<td>96</td>
<td>3.13</td>
</tr>
<tr>
<td>Project managers allocation</td>
<td>Non Civil Eng.</td>
<td>12</td>
<td>10</td>
<td>3</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>Civil Eng.</td>
<td>65</td>
<td>78</td>
<td>68</td>
<td>3</td>
</tr>
<tr>
<td>Overhead allocation</td>
<td>Non Civil Eng.</td>
<td>12</td>
<td>10</td>
<td>3</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td>Civil Eng.</td>
<td>68</td>
<td>83</td>
<td>60</td>
<td>2.9</td>
</tr>
<tr>
<td>Cash distribution &amp; borrowings</td>
<td>Non Civil Eng.</td>
<td>12</td>
<td>10</td>
<td>3</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td>Civil Eng.</td>
<td>68</td>
<td>83</td>
<td>60</td>
<td>2.73</td>
</tr>
</tbody>
</table>

Table 5.9: Results of the Chi-square crosstabs analysis for knowledge improved upon filling in the bidding forms vs subject of study.

In summary, participants’ responses indicate fair knowledge improvement upon decision on bids, project managers and overhead allocation, more than fair improvement upon decision on labour allocation and less than fair on cash distribution and borrowings.
Although the results of the Chi-square test show that some of these scores were given at random, further analysis showed that participants’ level of education may be a factor that influenced these decisions. Participants with a Civil Engineering background gained more knowledge from these aspects of the game, than those with non Civil Engineering background. The low scores given to knowledge improved upon cash distribution and borrowings were independent of the participants’ background, indicating that the whole population gained poor knowledge of this aspect of the simulation game.

It can therefore be concluded that fair knowledge improvement was obtained by participants as a result of decisions on bids, labour and project managers allocation. However, less knowledge improvement occurred as a result of decisions made upon, cash distribution and overhead allocation. The participants’ subject of study is also a contributing factor influencing their knowledge improvement. The scores given by participants with Civil Engineering background were more than those given by non Civil Engineers. This indicates that Civil Engineers are more receptive and build upon previously gained experience in this subject domain. However, the low scores given to knowledge improved upon decisions on overhead allocation and cash distribution and borrowings were not given at random, nor were they dependent upon the participants’ background. This indicates a weakness in the simulation game to promote such knowledge satisfactorily.

iii. Knowledge improved in other areas of construction management

As a result of the decision making process and the interaction with the simulation game, participants are expected to improved their knowledge in other areas of construction management described in section 4.4.1 and listed below:

- Organisation theory
- Planning
- Forecasting
- Financial management
- Marketing
• Group behaviour
• Communication
• Competitive bidding

Table 5.10 presents participants’ responses expressed as percentages and mean scores of knowledge improved in other areas of construction management. It can be seen that mean scores given to knowledge improvement fall in the ‘poor’ region. In addition the given percentages of frequency of scores decline from being higher at the ‘poor’ region to being lower at the ‘fair’ and ‘good’ region.

<table>
<thead>
<tr>
<th>Tested parameters</th>
<th>Response (%)</th>
<th></th>
<th></th>
<th>Average score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poor</td>
<td>Fair</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Organisation theory</td>
<td>55</td>
<td>29</td>
<td>16</td>
<td>1.98</td>
</tr>
<tr>
<td>Planning</td>
<td>40</td>
<td>34</td>
<td>27</td>
<td>2.50</td>
</tr>
<tr>
<td>Forecasting</td>
<td>43</td>
<td>34</td>
<td>23</td>
<td>2.31</td>
</tr>
<tr>
<td>Financial management</td>
<td>36</td>
<td>34</td>
<td>30</td>
<td>2.58</td>
</tr>
<tr>
<td>Marketing</td>
<td>65</td>
<td>26</td>
<td>9</td>
<td>1.82</td>
</tr>
<tr>
<td>Group behaviour</td>
<td>38</td>
<td>31</td>
<td>31</td>
<td>2.56</td>
</tr>
<tr>
<td>Communication</td>
<td>32</td>
<td>32</td>
<td>36</td>
<td>2.75</td>
</tr>
<tr>
<td>Competitive bidding</td>
<td>40</td>
<td>32</td>
<td>28</td>
<td>2.61</td>
</tr>
</tbody>
</table>

Table 5.10: Percentage frequency of scorings for knowledge improved in areas of construction management

To test the Null Hypothesis that these scores are given at random, Table 5.11 shows the results of Chi-square test and the corresponding significance. These results show that, for a level of significance >0.05 the null hypothesis is accepted for knowledge improved in financial management, group behaviour, communication and competitive bidding, hence, these scores are given at random. However, for values of significance of <0.05 the null hypothesis is rejected for knowledge improved in organisation theory, planning, forecasting and marketing, indicating that these scores were not given at random.
<table>
<thead>
<tr>
<th>Tested parameters</th>
<th>H value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organisation theory</td>
<td>56.75</td>
<td>0.000</td>
</tr>
<tr>
<td>Planning</td>
<td>6.11</td>
<td>0.04</td>
</tr>
<tr>
<td>Forecasting</td>
<td>15.86</td>
<td>0.0005</td>
</tr>
<tr>
<td>Financial management</td>
<td>1.66</td>
<td>0.44</td>
</tr>
<tr>
<td>Marketing</td>
<td>115.03</td>
<td>0.00</td>
</tr>
<tr>
<td>Group behaviour</td>
<td>2.04</td>
<td>0.36</td>
</tr>
<tr>
<td>Communication</td>
<td>1.02</td>
<td>0.50</td>
</tr>
<tr>
<td>Competitive bidding</td>
<td>5.12</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Table 5.11: Summary of the level of significance from the Chi-square test

Table 5.12 presents a summary of the Kruskal Wallis analysis of variance, to test the Null Hypothesis that knowledge improved in ‘organisation theory’, ‘planning’ and ‘forecasting’ are independent of the participants’ background. These results show that, for a level of significance of <0.05, participants’ ‘subject of study’ may be a contributing factor in influencing the participants knowledge improvement in areas of ‘organisational theory’, ‘planning’ and ‘marketing’.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Organisation theory</th>
<th>Planning</th>
<th>Forecasting</th>
<th>Marketing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.5714</td>
<td>0.1529</td>
<td>0.6751</td>
<td>0.7785</td>
</tr>
<tr>
<td>level of education</td>
<td>0.1293</td>
<td>0.5589</td>
<td>0.1424</td>
<td>0.0949</td>
</tr>
<tr>
<td>Subject of study</td>
<td>0.0197</td>
<td>0.0214</td>
<td>0.0091</td>
<td>0.855</td>
</tr>
<tr>
<td>Number of time they took part</td>
<td>0.6065</td>
<td>0.6339</td>
<td>0.6078</td>
<td>0.1212</td>
</tr>
<tr>
<td>Type of experience</td>
<td>0.8083</td>
<td>0.3256</td>
<td>0.7453</td>
<td>0.8433</td>
</tr>
<tr>
<td>Years of experience</td>
<td>0.8545</td>
<td>0.2419</td>
<td>0.1230</td>
<td>0.3416</td>
</tr>
</tbody>
</table>

Table 5.12: Results of the Kruskal Wallis analysis of variance

Table 5.13 shows a summary of the distribution of scores given by the civil engineers and the non civil engineers. These results indicate that, although all scores fall in the poor
region, participants with civil engineering subject of study, gained higher scores than those given by non civil engineers.

<table>
<thead>
<tr>
<th>Decisions on Subject of study</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Average scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organisational theory Non Civil Eng.</td>
<td>19</td>
<td>5</td>
<td>1</td>
<td>1.44</td>
</tr>
<tr>
<td>Civil Eng.</td>
<td>111</td>
<td>64</td>
<td>36</td>
<td>2.04</td>
</tr>
<tr>
<td>Planning Non Civil Eng.</td>
<td>15</td>
<td>7</td>
<td>3</td>
<td>1.92</td>
</tr>
<tr>
<td>Civil Eng.</td>
<td>79</td>
<td>72</td>
<td>60</td>
<td>2.50</td>
</tr>
<tr>
<td>Forecasting Non Civil Eng.</td>
<td>16</td>
<td>8</td>
<td>1</td>
<td>1.56</td>
</tr>
<tr>
<td>Civil Eng.</td>
<td>86</td>
<td>73</td>
<td>52</td>
<td>2.29</td>
</tr>
</tbody>
</table>

Table 5.13: Crosstabs analysis for the knowledge improves in areas of Construction Management vs participants' subject of study

In summary, the analysis of results showed poor knowledge improvement in participants’ knowledge in other areas of construction management, although some of these scores were given at random. However, participants’ responses to knowledge gained in 'organisational theory', 'planning' and 'forecasting', were not given at random and were dependent on the participants’ subject of study. Particularly low scores were given by participants with non Civil Engineering background. Since, knowledge improvement in these areas of construction management is dependent on the interaction with the simulation game, Section 5.2.3 examines the association between these scores and knowledge improved upon decisions made to fill in the decision forms.

iv. Participants’ values and attitudes towards the simulation game

This section describes the analysis of the participants’ response to the value of the simulation game:

- As learning medium:
- For demonstrating the inter-related nature of construction industry:
For encouraging team work;

For promoting interest in areas outside participants' particular experience.

Table 5.14 presents the responses of participants, expressed as percentages, and the mean scores given to different aspects of the simulation game. It can be seen that scores greater than 3 are given to the values of the simulation game as a learning medium, its value to 'demonstrate the inter-related nature of construction industry and for encouraging team work', indicating a 'fair-good' value. A mean score of 2.9 (the results of a two tailed t-test shows, at 95% confidence level, shows that this values is not significantly <3) given to the value of the simulation game to 'promote interest in areas outside participants' particular experience', indicating a 'fair' value. It can also be seen from Table 5.14 that, for the first three tested parameters, the lowest proportion of participants fall in the 'poor' region, increase in the 'fair' region and are highest at the 'good' region. However, the opposite pattern can be observed for the value of the simulation game to promote interest in areas outside participants' particular experience.

<table>
<thead>
<tr>
<th>Value of the simulation game</th>
<th>Response (%)</th>
<th></th>
<th></th>
<th>Average score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poor</td>
<td>Fair</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>As learning medium</td>
<td>27</td>
<td>32</td>
<td>41</td>
<td>3.1</td>
</tr>
<tr>
<td>To demonstrate the inter-related nature of</td>
<td>22</td>
<td>25</td>
<td>53</td>
<td>3.4</td>
</tr>
<tr>
<td>construction industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To encourage team work</td>
<td>12</td>
<td>27</td>
<td>61</td>
<td>3.6</td>
</tr>
<tr>
<td>To promote interest in areas outside</td>
<td>38</td>
<td>30</td>
<td>32</td>
<td>2.9</td>
</tr>
<tr>
<td>participants' particular experience</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.14: Percentage frequency and mean scores given to the value of the simulation game

Table 5.15 depicts the values of Chi-square and the associated values of significance under H0 (H0: Probability of scores given at random). These results show that, for values of significance of <0.05, the probability associated with H0 is rejected, for the value of the simulation game as a learning medium, its value to demonstrate the inter-related nature of construction industry, and to encourage team work, concluding that participants' response to these aspects of the simulation game, were not given at random. However, the null
hypothesis is accepted for the value of the simulation game to promote participants' interest in areas outside their particular experience, concluding that these scores were given at random and do not reflect a true opinion of the population sample.

<table>
<thead>
<tr>
<th>Tested parameters</th>
<th>H value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>As learning medium</td>
<td>7.48</td>
<td>0.024</td>
</tr>
<tr>
<td>To demonstrate the inter-related nature of construction industry</td>
<td>39.59</td>
<td>0.000</td>
</tr>
<tr>
<td>To encourage team work</td>
<td>86.70</td>
<td>0.000</td>
</tr>
<tr>
<td>To promote interest in areas outside participants’ particular experience</td>
<td>2.55</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Table 5.15: Summary of the level of significance from the Chi-square test

Table 5.16 shows the results of the Kruskal Wallis one way analysis of variance test. These results indicate that, for a level of significance of <0.05, participants’ value of the simulation game to demonstrate the inter-related nature of decisions in the construction industry may be dependent on their level of education. It also shows that their value of the simulation game ‘as a learning medium’ is dependent on the number of times they took part in MERIT2.'

<table>
<thead>
<tr>
<th>Value vs. background</th>
<th>Value of MERIT2 as learning medium</th>
<th>Value of MERIT2 to demonstrate the inter-related nature of construction industry</th>
<th>Value of MERIT2 to encourage team work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.1816</td>
<td>0.5720</td>
<td>0.8581</td>
</tr>
<tr>
<td>Level of education</td>
<td>0.4113</td>
<td>0.0453</td>
<td>0.2189</td>
</tr>
<tr>
<td>Subject of study</td>
<td>0.2589</td>
<td>0.4788</td>
<td>0.7444</td>
</tr>
<tr>
<td>Number of times MERIT2 played</td>
<td>0.0630</td>
<td>0.5193</td>
<td>0.9806</td>
</tr>
<tr>
<td>Years of experience</td>
<td>0.6608</td>
<td>0.6157</td>
<td>0.3927</td>
</tr>
</tbody>
</table>

Table 5.16: Kruskal Wallis Analysis of Variance for the value of the simulation game
For a closer examination of these results, Table 5.17 shows the group behaviour towards these aspects of the simulation game, indicated by the mean scores and the frequency distribution of these scores. Fair-good scores are given by second time players, to the value of the simulation game as a learning medium, and a mean score of 2.9 falling in the ‘fair’ region are given by first time participants. Although participants with <BSc level of education form only 10.9% of population sample, they gave an average score of 3.9 falling in the good-very good region for the value of the simulation game to demonstrate the interrelated nature of construction decisions.

<table>
<thead>
<tr>
<th>Value Background</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Mean scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>as a learning medium</td>
<td>Played twice</td>
<td>37</td>
<td>38</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>Played once</td>
<td>15</td>
<td>22</td>
<td>44</td>
</tr>
<tr>
<td>To demonstrate the interrelated nature of com. decisions</td>
<td>B.Sc.</td>
<td>3</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>BSc or higher</td>
<td>49</td>
<td>56</td>
<td>106</td>
</tr>
</tbody>
</table>

Table 5.17: Crosstabs analysis for the value of the simulation game.

In summary, the results indicate that participants are mostly in favour of the simulation game as a tool for encouraging team work, and to demonstrate the inter-related nature of decisions in the construction industry. Participants are less in favour of the value of the simulation game as a learning tool and least of its value to promote interest in areas outside their particular experience. The simulation game as a learning medium is more valued by second time participants, indicating that taking part in the simulation game for the second time reinforces the knowledge gained from the first time. In addition the value of the simulation game to demonstrate the interrelated nature of construction decisions, is mainly appreciated by those with less than BSc level of education, indicating that the simulation game has a good value in raising this awareness, even to those who are not the targeted users of MERIT?.

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v. Participants' responses towards the enjoyment of the simulation game

This section investigates the participants' responses to the enjoyment of the simulation game. Table 5.18 shows that the average score given to the enjoyment of the simulation game is 3.4, and that the highest proportions of scores falls in the 'good' region, and the lowest falls in the 'poor' region. Table 5.18 shows the value of Chisquare test and the corresponding value of significance, under HO (HO: is the probability of scores given at random), indicating that for a value of significance of <0.05 the Null Hypothesis is rejected and that scores to the enjoyment of the simulation game are not given at random.

<table>
<thead>
<tr>
<th>Enjoyment of the simulation game</th>
<th>Response (%)</th>
<th>Average score</th>
<th>Value of Chisquare</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>21</td>
<td></td>
<td>7.48</td>
<td>0.024</td>
</tr>
<tr>
<td>Fair</td>
<td>29</td>
<td>3.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.18: Analyses of the participants' scores towards their enjoyment of the simulation game

The results of the Kruskal Wallis One Way Anova Analysis of Variance, are summarised in Table 5.19, indicating that the participants' response to the enjoyment of the simulation game is dependent on the number of times they took part in MERIT2, and on their years of experience.

<table>
<thead>
<tr>
<th>Background</th>
<th>Chisquare level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.4694</td>
</tr>
<tr>
<td>Level of education</td>
<td>0.2899</td>
</tr>
<tr>
<td>Subject of study</td>
<td>0.1396</td>
</tr>
<tr>
<td>Number of times MERIT2 played</td>
<td>0.0400</td>
</tr>
<tr>
<td>Type of experience</td>
<td>0.7959</td>
</tr>
<tr>
<td>Years of experience</td>
<td>0.0087</td>
</tr>
</tbody>
</table>

Table 5.19: Crosstabs analysis for the frequency of scores given to the enjoyment of the simulation game vs type of experience

For a closer examination of the behaviour of these groups, Table 5.20 show a summary of the frequency of scores given by these participants. Higher scores are given by participants who took part in the simulation game twice and by the less experienced participants.

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Table 20: Analysis of frequencies of scores given to the enjoyment of the simulation game in relation to participants' background

In summary these results indicate that in general, participants responses towards the enjoyment of the simulation game was not given at random, indicating that they have fairly enjoyed the simulation game, particularly by participants who took part in the simulation game twice and have <3 years of experience. Conclusions drawn from the previous section also indicated that second time participants value the simulation game more than those who took part for first time. Accordingly section 5.2.3 examines the association between the enjoyment of the simulation game and its value. As for the less experienced participants, this is the target group of MERIT2, and their enjoyment of the simulation game is a measure of the effectiveness of this tool.

**Participants' reasons for not enjoying the simulation game**

The questionnaire survey asked participants who gave scores of <3 (forming 20% of the population), to tick one or more of options shown in Table 5.21, illustrating the reasons for not enjoying the simulation game.
<table>
<thead>
<tr>
<th>Reasons</th>
<th>% Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulties in understanding the simulation game</td>
<td>26%</td>
</tr>
<tr>
<td>Not enough time for making decisions</td>
<td>16%</td>
</tr>
<tr>
<td>Not satisfied with the simulation game briefing and introduction</td>
<td>22%</td>
</tr>
<tr>
<td>Did not appreciate the relevance of the simulation game</td>
<td>11%</td>
</tr>
<tr>
<td>Other reasons</td>
<td>24%</td>
</tr>
</tbody>
</table>

Table 5.21: The distribution of percentages of participants who did not enjoy the simulation game for various reasons

Participants’ general comments, expressing other reasons for not enjoying the simulation game are reported and categorised as shown below:

1. The environment of the simulation game:

   a. Technical operation
      - Inability to get the majority of the supplied programs to work.

   b. Running procedures
      - The operation of the simulation game being divided into two batches of contestants.
      - Not enough time for making decisions, caused problems in arranging meeting acceptable to each simulation game members.
      - Appendix 'A' misleading, since the revised %'s were never given hence, making future planning difficult. The effect of varying the mark-up was impossible to determine.
      - All problems arose from trying to find enough time to properly digest and play the simulation game, as well as dealing with regular staff changes within the original team.
      - Incorrect inputs of our decisions at rounds 1 and 2 made the next round rather academic.
      - The rules and effects of the various parameters were not sufficiently explained.
      - No explanation on the number of points rewarded
      - Initial instructions were poor, and working individually limited time to interpret rules.
2. The structure of the simulation game

- A lot of information to take in and understand. It took until the last round to fully appreciate the simulation game. May be second entry would be easier.
- Lack of feedback on position, in time to influence next round decisions.
- The simulation game did not seem realistic, too much a computer model.
- Poor interface.
- Not able to identify where errors are being made, therefore was unable to learn from the simulation game.
- Inconsistency of input at each round, confusing and inconsistent method of changing resource allocation and labour.
- Not enough feedback regarding the effort of decision making.
- The success of the company seemed to depend on the number of jobs awarded and have no relation to the original brief, where slow growth was recommended.
- Implications of some decisions were not clear and hidden.
- Not enough feedback for why we were not awarded jobs.
- The rules were such that as intended (i.e. sound business basis) was not conclusive to winning, e.g., short terms scored higher than longer term sound business strategy.
- Lack of feedback, and therefore unable to learn from the simulation game.

3. De-motivated participants

- Familiarity with the simulation game having played twice previously.
- Not good communication between the members of the team.
- Incorrect analysis on teams input sheets.
- Found numerical data too complicated.
- The sole purpose of the simulation game was to gain CPD days, that I do not need.
- Not realistic enough and boring.
- Errors in the input of information by the co-ordinates, complicated the simulation game and did not give an accurate feel for how the simulation game should have operated.
- Errors were made when decisions were entered into the computer. Therefore, the following months decisions were affected.
• Once one poor decision was made, performance was irretrievable.

These comments are discussed further in section 5.4 of this chapter.

vi. Participants' interest to take part in MERIT2 again

Participants were asked to express their interest in taking part in MERIT again. The results of this enquiry showed that, 53% of the participants expressed their interest to take part in MERIT2 again, while 47% expressed disinterest. To investigate whether the participants' opinion is dependent of their background, the Kruskal-Wallis one way Anova analysis of variance was carried out. The results of this test are summarised in Table 5.22 indicating that participants interest to play the simulation game again is dependent of their ages, number of times they played the simulation game and their years of experience.

<table>
<thead>
<tr>
<th>Background</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.0375</td>
</tr>
<tr>
<td>Level of education</td>
<td>0.7825</td>
</tr>
<tr>
<td>Subject of study</td>
<td>0.0237</td>
</tr>
<tr>
<td>Number of times they participated</td>
<td>0.0112</td>
</tr>
<tr>
<td>Type of experience</td>
<td>0.3433</td>
</tr>
<tr>
<td>Years of experience</td>
<td>0.027</td>
</tr>
</tbody>
</table>

Table 5.22: Kruskall Wallis Analysis of variance for the participants interest to take part in MERIT2 again

Table 5.23 shows the results of Chisquare crosstabs analysis, indicating that there is significant difference in the distribution of frequencies presenting participants’ opinion to take part in MERIT2. These results indicate that higher number of the younger age group and the less experienced group showed interest in taking part in the simulation game again, than the older and the less experienced group. In addition, higher frequency of participants who took part in the simulation game once expressed interest in taking part again, than the second time participants.
Table 5.23: Chisquare crosstabs analyses of frequencies of participants in relation to their background

<table>
<thead>
<tr>
<th>Interest to take part again</th>
<th>Backgrounds</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ages 25 or more</td>
<td>41</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>Ages &lt;25</td>
<td>69</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>Took part once</td>
<td>92</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Took part twice</td>
<td>63</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>&gt;3 years</td>
<td>44</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>&lt;3 or = years</td>
<td>82</td>
<td>56</td>
</tr>
</tbody>
</table>

More than 50% of the population expressed their interest to take part in the simulation game again. Participants' interest to take part in MERT2 again, is considered as an indicator of motivation (Chapters 2, 3). The results also showed that the younger age group and the less experienced group of participants showed higher response to take part in the simulation game again. A noticeably higher percentage of first time participants showed interest to take part again, than second time participants.

vii. Participants’ responses to the relevance of MERIT2

This part of the survey investigated the relevance of the simulation game to:

- improving the participants’ professional abilities;
- their practical experience at the time the simulation game was played.

Table 5.24 shows summary of frequencies of the participants’ responses, where 49% of the sample population found the simulation game relevant to improving their professional abilities, and 30% of the sample population found the simulation game of relevance to their particular experience. Table 5.24 also shows results of the Chi-Square test, indicating that there is no significant difference between the participants’ opinion (for the simulation game improvement to their professional ability), and that these decision are made at a random (L.S = 0.961). However, for a level of significance of <0.05, the results show that
the participants' response to the relevance of the simulation game to their particular experience was not given at random.

<table>
<thead>
<tr>
<th>Relevance of MERIT2</th>
<th>% Voted for relevance</th>
<th>Values of Chisquare</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>For improving participants professional abilities</td>
<td>49%</td>
<td>0.1525</td>
<td>0.6961</td>
</tr>
<tr>
<td>To participants practical experience</td>
<td>30%</td>
<td>37.4407</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Table 5.24: Analysis of frequencies for the relevance of the simulation game, and the results of the Chisquare analysis

To investigate whether these responses were dependent on the participants' background, the Kruskall Wallis analysis was carried out and the summary of these results are presented in Table 5.25. These results indicate that participants' response to the relevance of the simulation game to their practical experience is dependent on their age, while their response to the relevance of the simulation game to their professional abilities is dependent on years of experience.

<table>
<thead>
<tr>
<th>Background</th>
<th>Relevance to improving professional abilities</th>
<th>Relevance to practical experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.82</td>
<td>0.014</td>
</tr>
<tr>
<td>Level of education</td>
<td>0.23</td>
<td>0.81</td>
</tr>
<tr>
<td>Subject of study</td>
<td>0.04</td>
<td>0.81</td>
</tr>
<tr>
<td>Number of times MERIT2 played</td>
<td>0.34</td>
<td>0.27</td>
</tr>
<tr>
<td>Type of experience</td>
<td>0.59</td>
<td>0.11</td>
</tr>
<tr>
<td>Years of experience</td>
<td>0.014</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Table 5.25: Kruskal Wallis Analysis of Variance for the relevance of the simulation game in relation to participants background

For a closer examination of these groups' behaviour, the results of the Chisquare Crosstabs analysis of frequencies are shown in Table 5.26. These results show that about a third of
the less experienced group and about half of the more experienced group found the simulation game relevant to improving their professional abilities. More than half of the older ages group and about half of the younger age group found the simulation game relevant to their practical experience.

<table>
<thead>
<tr>
<th>Relevance</th>
<th>Backgrounds</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>To professional</td>
<td>3 or less years experience</td>
<td>38</td>
<td>100</td>
</tr>
<tr>
<td>abilities</td>
<td>&gt; 3 years experience</td>
<td>33</td>
<td>65</td>
</tr>
<tr>
<td>To practical</td>
<td>Ages 25 or more</td>
<td>64</td>
<td>41</td>
</tr>
<tr>
<td>experience</td>
<td>Ages &lt;25</td>
<td>62</td>
<td>69</td>
</tr>
</tbody>
</table>

Table 5.26: Chisquare crosstabs analysis of frequencies for the relevance of the simulation game

In summary, the relevance of MERIT2 to the participants experience, shows a positive indication to its value to promote learning for CPD.

Participants’ comments towards the relevance of the simulation game

Participants were also asked to comment on how they found the simulation game relevant to improving their professional abilities and, to its relevance to their existing experience in construction management. These comments were summarised below:

- Team leaders showed that the simulation game was a relevant tool for improving their leadership qualities in organising and advising others in chaired meetings. Improved communication skills as they had to make the final decisions when a conflict developed between other members of the team.

- Members of the team, found that simulation game in general improved their communication skills, and helped to discuss and consider decisions carefully within a ‘team’. This helped in increasing their awareness of ‘team work’ to reach decisions and share responsibilities, and to improve negotiation and compromise skills.
As one of the participants put it, ‘I learnt quite a lot about the simulation game from discussion with colleagues, it acted as a simulation for discussion about management, analysing problems and coming up with solutions’.

The simulation game brought together and made use of existing skills and knowledge, and observations on how people interact in meetings and how to handle people.

Raised the awareness of the complex nature of industry and gave wider view.

Those who were not Civil Engineers stated that ‘the simulation game made them enter areas that they had no experience in and, would otherwise not been aware of. Also, improved their understanding of a field of work other than their own.

A better understanding of project management, financial management, competitive bidding and construction planning of resources by levelling of users and finances and control as well as cash flow and processes involved in bidding, forecasting, plus balancing needed while bidding for jobs.

Seeing the decisions being made from the contractors point of view and Civil Engineering contracting involving tendering and winning jobs.

5.2.3 Response independency

This section investigates whether certain responses given by the participants are dependent on other responses. To assist this enquiry, values of Pearson correlation coefficient ‘R’ are determined. This is a measure of the linear association between two variables, and its value ranges between -1 (a perfect negative relationship) and +1 (a perfect positive relationship). A value of 0 indicates no linear relationship. This investigation is carried to examine the following:

1. The association between knowledge improved upon the decision making process, and the introductory stage of the simulation game.

Table 5.27 depicts values of R as a measure of association between the introductory stage of the simulation game and the knowledge improved upon filling in the decision forms. Although the results show that there is a positive association between these variables (i.e.,
the increase of scores of one parameter is associated with the increase of scores in the other), and generally stronger between the knowledge improvement and the quality of information given in the manual, these results do not reflect a strong association between these parameters.

<table>
<thead>
<tr>
<th>Decisions on</th>
<th>Values of R vs the introductory stage of the simulation game</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Introduction and briefing</td>
</tr>
<tr>
<td>Bids</td>
<td>0.18</td>
</tr>
<tr>
<td>Labour allocation</td>
<td>0.23</td>
</tr>
<tr>
<td>Project manager allocation</td>
<td>0.20</td>
</tr>
<tr>
<td>Overhead allocation</td>
<td>0.12</td>
</tr>
<tr>
<td>Cash distribution and borrowing</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Table 5.27: Values of R for the introductory stage of the simulation games vs decision made for filling in the bidding forms

2. Knowledge improved upon filling in the decision forms is independent of knowledge improved in other areas of construction management.

Values of Pearson's correlation coefficient shown in Table 5.27 indicate that the association between the knowledge improved upon decisions made for filling in the bidding forms and other areas of construction management, is positive. The strongest association lies within the knowledge improved upon decisions on ‘bids, labour and project managers allocation’ and areas of ‘planning, forecasting and organisational theory’. The strength of this association however, is less for decisions on overhead allocation and cash distribution borrowings.
Other areas of construction management & Decisions on

<table>
<thead>
<tr>
<th>Other areas of</th>
<th>Decisions on</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bids</td>
</tr>
<tr>
<td>Organisation theory</td>
<td>0.30</td>
</tr>
<tr>
<td>Planning</td>
<td>0.30</td>
</tr>
<tr>
<td>Forecasting</td>
<td>0.37</td>
</tr>
<tr>
<td>Marketing</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Table 5.28: Values of R for knowledge improved upon the decision making process vs other areas of construction management

3. Knowledge improved vs value of the simulation game.

Table 5.29 show values of R, indicating a positive association between knowledge improvement and the value of the simulation game. The strongest correlation is between knowledge improved upon decisions made on bids, labour allocation, project managers allocation and the value of the simulation game as a learning medium and to demonstrate the inter-related nature of construction industry. This association however, is less for decisions made on overhead allocation and least for cash distribution borrowings. The results also show weak association between knowledge gained in these areas and the participants’ value of the simulation game to promote team work and its value to promote interest in areas outside participants’ particular experiences.

Table 5.29 also shows a weak and negative association between ‘participants’ interest to take part in the simulation game again’ and ‘their knowledge improvement’.
Decisions on Value of the Bids Labour Project Overhead Cash simulation game allocation managers allocation distribution borrowings

As learning medium 0.44 0.46 0.42 0.36 0.28

To demonstrate the inter-related nature of construction industry 0.44 0.41 0.43 0.37 0.29

To encourage teamwork 0.24 0.27 0.20 0.05 0.13

To promote interest in areas outside participants’ particular experience 0.29 0.27 0.20 0.21 0.20

Interest to play again -0.12 -0.12 -0.09 -0.14 -0.04

Table 5.29: Value of R for knowledge improvement vs value of the simulation game

4. The enjoyment of the simulation game vs the introduction of the simulation game.

The results in Table 5.30, show that there is a positive association between enjoyment and the introductory stage of the simulation game, indicating that high scores to enjoyment are associated with the high scores given to the introduction of the simulation game.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Enjoyment of the simulation game</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction and briefing to the simulation game</td>
<td>0.36</td>
</tr>
<tr>
<td>Quality of information given before starting the simulation game,</td>
<td>0.39</td>
</tr>
<tr>
<td>Overall information given for filling in the bidding forms.</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Table 5.30: Values of R for the introduction of the simulation game vs enjoyment
5. Enjoyment of the simulation game vs participants' value of the simulation game.

The results in Table 5.31 indicate that there is a positive association between the participants' enjoyment of the simulation game and their value of the simulation game as a learning medium, to demonstrate the inter-related nature of construction industry, to promote interest in areas outside participants' particular experience, and to encourage teamwork. This indicates that the high scores given to the enjoyment of the simulation game are dependent on the high scores given to the value of the simulation game. However, the association between participants enjoyment of the simulation game and their interest to play again is much weaker, indicating that interest to take part again is less dependent on the enjoyment of the simulation game.

<table>
<thead>
<tr>
<th>Value of the simulation game</th>
<th>Enjoyment of the simulation game</th>
</tr>
</thead>
<tbody>
<tr>
<td>As learning medium</td>
<td>0.48</td>
</tr>
<tr>
<td>To demonstrate the inter-related nature of construction industry</td>
<td>0.47</td>
</tr>
<tr>
<td>To encourage teamwork</td>
<td>0.36</td>
</tr>
<tr>
<td>To promote interest in areas outside participants' particular experience</td>
<td>0.44</td>
</tr>
<tr>
<td>Interest to play again</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Table 5.31: Values of R for enjoyment vs value of the simulation game

5.2.4 Summary of results

Participants' background.

The average ages of the surveyed population sample is 25 years, comprising mainly Civil Engineers, with B.Sc. or higher level of education. Approximately two thirds of the population worked for contractors, and a third worked for consultants. More than half of the population had less than three years of experience. A third of the population took part in MERIT2 once and two thirds took part in MERIT2 twice. Although, the size of this sample is large enough to produce reliable results for the evaluation of different aspects of MERIT2, this sample does not consist of a broad range of different groups of participants.
to obtain comparable views and results. However, comparisons have been made wherever possible to produce an overview of the behaviour of subgroups despite the differences of sizes between these groups. For example, both groups of participants with ‘Civil Engineering subject of study’ and with ‘BSc or higher level of qualifications’ formed 89% of the sample population. This makes it difficult to compare the views of these groups with those who are not qualified Civil Engineers and have less than BSc level of education. Therefore, observations upon the behaviour of these groups were made, to obtain indications of comparison.

Efficiency of the introductory stage of MERIT2.
Participants’ response to the introductory stage of the simulation game was ‘fair’, indicating that this stage was neither poor nor efficient. The results also showed that these responses were not given at random (i.e. presenting true population opinion) and are independent of the participants’ background. However, some observation were made, indicating that the more experienced participants approved more of the ‘quality of information given in the manual and information given to fill in the decision forms’, than the less experienced participants.

Knowledge improvement through taking part in MERIT2
Neutral responses were given to the participants’ knowledge improvement upon decision on bids, project managers and overheads, indicating that the simulation game raised the participants awareness in these areas, however a ‘good’ response to knowledge improved upon labour allocation indicate that participants improved their knowledge in this area. The low responses to knowledge gained over cash distribution and borrowing, indicated poor knowledge gained and dissatisfaction with this aspect of the simulation game. Although, these results evidenced that Civil Engineers were more satisfied (than the non Civil Engineers) with the knowledge improved upon the first four sets of decision, knowledge gained in the area of cash distribution and borrowing remained poor with both groups.
As a result of participants knowledge improvement upon the decision making process and the interaction with the simulation game, participants are expected to improve their knowledge in other areas of construction management. However, random responses were given to some of these areas, reflecting unreliable responses (could be as a result of the long listed nature of questions). These responses were not given at random, and poor knowledge was gained in areas of organisational theory, planning, forecasting and marketing. The results also showed that the participants’ subject of study may be a contributing factor to knowledge improved in these areas, although knowledge improvement still gained poor scores by both groups of participants (Civil Engineers and Non Civil Engineers).

**Value of MERIT2**

MERIT2 was rated by the population sample as a tool that has a fair value as a learning medium. This rating was dependent on the number of times participants took part in the simulation game. However, second time participants, valued the simulation game more and ranked it as ‘a good learning medium’ than those who took part once. MERIT2 was rated to be of good value for demonstrating the interrelated nature of construction decision, participants with less than BSc level of education rated this aspect of the simulation game as being very good, giving a score considerably higher than the targeted participants with BSc s’ or more. Independent of their backgrounds, participants rated the simulation game as a valuable tool for encouraging teamwork.

**Enjoyment of MERIT2**

MERIT 2 was well enjoyed by the sample population. The higher rating for the enjoyment of the simulation game came from second time participants, and the more experienced groups.

**Interest to take part again**

More that half of the sample population expressed interest in taking part in the simulation game again. The highest responses were given by the younger groups, the less experienced group and first time participants.
Relevance of MERIT2

Almost half of the population approved of the relevance of the simulation game for improving their professional abilities. Nearly a third of the population found the simulation game relevant to their practical experience. Participants ages and years of experience were the contributing factors for influencing these decision.

Association between responses

The association between various responses showed:

- Positive but weak linear association between knowledge improved upon the decision making process and the introductory stage of the simulation game;

- Positive and some linear association between knowledge improved upon decision on bids, labour and project managers allocation vs knowledge improvement in planning, forecasting and marketing. This association was weaker for the knowledge improved upon decision on ‘overhead allocation’ and ‘cash distribution borrowings’ vs ‘knowledge in other areas of construction management’.

- Positive and relatively linear association between knowledge improved upon decision on bids, labour and project managers allocation and overhead allocation.

- Positive and some association between the enjoyment of the simulation game and the introductory stage of the simulation game

- Positive and fairly strong association between the ‘enjoyment’ and ‘value’ of the simulation game, and between ‘enjoyment of the simulation game’ and ‘interest to take part again’.

5.2.5 Discussion of results and conclusions

This section discusses the results of the survey and concludes the main finding, in relation to the original aims and objectives of MERIT2 set during the pre-implementation stage and described in Chapter 4, section 4.4.1.
1. Did MERIT2 meet the educational aims and objectives it was originally created for?

The results of this survey indicate that MERIT2 partially achieved its educational aims and objectives originally planned, to meet the needs of its targeted users. This is evidenced by participants’ responses indicating that MERIT2 raised their awareness of the nature of construction management decision made within a construction company. Although these responses did not indicate a great satisfaction with this aspect of the simulation game, the latter gave participants the opportunity to constantly revise their targets and plans, deal with or enquire about situations where the actions or estimates of other companies thwart their own, appreciate the pressures of mark-ups and deal with problems of allocating and recruiting human resources. The results of this investigation also showed that MERIT2 critically promoted participants’ understanding of problems of cash restraints and overheads, indicated by less than satisfactory responses to this aspect of the simulation game.

The framework developed in Chapter 3 demonstrates the close links between the effectiveness of CAL tools, their operating environment, structure and its users. Therefore, a closer examination of the participants’ responses is carried out to investigate the effectiveness of MERIT2 as described below:

a. Operation of MERIT2. Consistent with the framework developed in Chapter 3, the efficiency of MERIT2 is considered to be dependent on two aspects:

i. The environment of the simulation game. Within the context of this research, the environment of MERIT2 refers to the handling of information before and when the simulation game is in operation. However, the neutral responses of participants to the introductory stage of the simulation game indicated that the postal procedures of ‘briefing and introduction to the simulation game’ reflected an unbiased opinion of the population sample independent of their background. Participants’ responses to the quality of information given in the manual and the information given for filling in the decision forms were also neutral. These responses did not indicate great satisfaction with this aspect of
the simulation game. However, the results showed that the participants’ previous experience may be a contributing factor influencing their decision. More experienced group of participants showed more satisfaction with this stage of the simulation game than the less experienced groups. These scores however, remained fairly neutral.

These results were further reinforced, when some participants expressed their reasons for not enjoying the simulation game. A number of participants who gave scores of <3 to the enjoyment of the simulation game, expressed their dissatisfaction with the way the simulation game was introduced, and not understanding major parts of the information given in the manual. Participants were also geographically disadvantaged by not having an easy option to contact the simulation game controller and clarify specific problems or difficulties.

Therefore these results suggest that the postal procedures of introducing the simulation game were not very satisfactory, with some indication that the quality of information given for understanding and handling the information given to play the simulation game, were of higher standard than expected, and did not match the needs and backgrounds of participants. The results also suggest that there is room for improvement to the quality of background information given in the manual and the information given for filling the decision forms, in such a way that will match the participants’ needs and educational goals.

ii. Technical operation. This stage is mainly concerned with the technical aspects of the computer simulation. Participants were not technically involved with processing the information with the computer simulation. However, some of the comments given by the participants indicated dissatisfaction with the amount of time given to reflect upon the output of results posted from previous rounds and the time left to make new sets of decisions. This highlights the importance of ‘reflection’ as a significant stage of the learning process, and that failure to reflect can cause failure in learning.
b. The structure MERIT2

Within the context of this research, participants’ knowledge improvement of the decision making process and other areas of construction management is considered a measure of the effectiveness of MERIT2 as a CAL tool to promote learning in construction management. Participants’ responses however, did not indicate that the simulation game proved highly effective in this respect. While some of the decisions made to fill in the bidding forms can be straightforward to start with, the nature of the simulation and the existence of a number of interchanging variables, results in influencing the decisions made in the next round. Failure in understanding the consequences of one wrong decision, may result in failure to understand how the simulation operates and the bases on which making the next set of decision are to be made. For example, bidding for new jobs, allocating labour and allocating project managers, can be worked out straight from the generated company reports, while allocating overheads and cash distribution depends on the understanding of the interlocking nature of the decisions made. When such interaction is not properly understood by the participants the decision making process is likely to becomes guess work. Therefore participants responses indicating dissatisfaction with the knowledge improved on cash distribution and borrowing could be a result of these reasons. This argument is further reinforced by participants’ comment on reasons for not enjoying the simulation game. Some of these reasons were repetitive complaints about not having enough feedback to understand the generated output reports and the consequences of the decisions made. Other reasons given for not enjoying the simulation game were, not having enough time to reflect upon the decisions made in the previous round and the results of the generated output reports.

‘Feedback’ and ‘reflection’ are the basic ingredients for effective learning (as previously highlighted in the study). These responses indicate that MERIT2 failed to effectively promote these aspects. The consequences of this is that a surface approach to learning is promoted, rather than a deep approach that implies remembering and applying new concepts.
2. Did MERIT2 effectively target the required learning strategies and promoted ‘off the job’ learning?

Chapter 4, section 4.2 described a framework developed by Armitage (1993), illustrating the stages of learning from simulation games. ‘Input’ assembles the introductory stage of METIT2, upon which the ‘decision making’ process depends on. This shows that problems associated with the postal procedures of introducing MERIT2 can influence the decision making process. However, more importantly, participants’ previous experience proved a contributing factor that influenced the participants decisions making process. Armitage’s framework also defines ‘feedback’ as an important stage of learning from simulation games. Participants’ comments indicated a lack of feedback generated from the simulation or from the simulation game controller to clarify any ambiguity within the generated reports. Accordingly, this can be handled by allowing participants enough time to reflect upon the results of decisions made. However, participants’ comments upon lack of time to reflect on the generated reports justifies their lack of understanding of the interlocking nature of decisions made, making the progressive rounds of the simulation game more confusing and complicated. Similarly, Fripp’s model of learning through simulations (section 4.2) illustrates the stages of experiential learning through simulation games, to promote ‘off the job’ learning. Similar observations can be made to detect the ineffectiveness of MERIT2.

Section 4.2 also highlighted the importance of the ‘aha-effect’ as a result of feedback generated from the simulation game, and its importance to take the participants to their first step of learning from MERIT2. This influences the development of new mental models or changing the existing ones. If these stages are effectively implemented, then the ‘progression’ in learning is more positive indicating a deep approach to learning.

The postal nature of the surveyed sample and the type of enquiry made, did not allow further investigation to test the participants’ knowledge before and after taking part in MERIT2. Nor did it allow for investigating the participants’ knowledge gained and their level of understanding of different concepts introduced by MERIT2. Therefore, section
5.3 investigates the effectiveness of MERIT2 as an education tool to support the conventional way of teaching construction management, and to test participants' knowledge improvement as a result of taking part in MERIT2.

3. Did MERIT2 prove motivating?
The difference between the 'effectiveness' of MERIT2 as a tool to promote learning in specific areas of construction management, and its 'value' to raise awareness of such knowledge, can be determined from measures of effective learning derived from literature reviewed in Chapters 2 and 3. The interpretation of these measures focus on the participants' value and enjoyment of the simulation game and the relevance of the simulation game to participants' practical experience and motivation to take part in MERIT2 again.

As previously argued, MERIT2 did not prove highly effective in promoting in depth learning in areas of construction management addressed earlier. However, participants' responses indicate that they highly valued the simulation game as a learning medium and as a tool to promote knowledge of the interrelated nature of construction decisions. MERIT2 also raised half of the sample populations' interest to take part again.

Surveyed responses also indicated that MERIT2 proved a valid tool to improve participants' professional abilities within the construction domain, and about a third of the population sample found MERIT2 relevant to their existing experience.

4. Did it meet the participants' educational needs?
To differentiate between the effectiveness of MERIT2 as a training tool and the performance of its participants, the given responses to different aspects of the simulation game were correlated to participants' background.

The results showed that, the participants' opinion of the introduction and briefing of the simulation game, were neutral and independent of their background. The results reflect the
view of the population sample upon this stage of the simulation game, indicating that it was not very satisfactory. However, some preferences were indicated by the more experienced group of participants, indicating more satisfaction with the quality of support material given to take part in the simulation game. This may suggest that the level of introduced information given may have been higher than the existing level of knowledge of the targeted participants (i.e., those with three or less years of experience) in view of their existing experience. This indicates that the responses given to the introductory stage of the simulation game were not very satisfactory.

Responses to the first three sets of decisions made (decisions on bids, labour allocation, project managers allocation), were dependent on the participants' discipline. Civil Engineers gave better response than the non Civil Engineers. This suggests that the simulation game could be more effective in promoting such knowledge when matching the existing knowledge of its targeted participants. The low scores given by all subgroups of participants to areas such as overhead allocation, or independent of participants' background, such as those given to decision on 'cash distribution and borrowings', suggest poor functionality of the simulation game in promoting such knowledge.

Although MERIT2 was rated by the sample population to have a good value as a learning medium, its greatest value was indicated by those who took part in MERIT2 more than once. This opinion was further reinforced by the desire of high proportions of first time participants to take part in the simulation game again. This interest was expressed by the younger participants and the less experienced groups, indicating that the value of this aspect of the simulation game motivated the targeted participants to take part again.

MERIT2 was also rated as a valuable tool for demonstrating the interrelated nature of construction decision making. This aspect was particularly highly valued by the non targeted participants with less than BSc level of education.

The following can be concluded from this survey:
1. MERIT2 can be more effective in meeting the educational aim and objectives as a training tool for CPD if:
   a. the introductory stage of the simulation game is improved and the quality of the preparatory material are improved;
   b. the quality of information in the manual is improved to suit participants’ to match participants’ background and previously gained experience;
   c. enough time is given to participants to make decisions after each round of the simulation game; and
   d. there is enough feedback generated from the output reports, clarifying the consequences of the decisions made for filling in the bidding forms.

2. Although MERIT2 facilitates all the stages of the experiential learning process. The nature of this survey could not detect the effectiveness of MERIT2 in promoting these strategies.

3. MERIT2 proved motivating through:
   a. participants’ response to their enjoyment of the simulation game,
   b. their value of the simulation game as a learning medium,
   c. their expressed interest to take their part again. Such interest was particularly expressed by first time participants; and
   d. its relevance to their practical experience within the construction industry.

4. MERIT2 met the participants’ educational needs in:
   a. demonstrating the nature of decisions made within a construction company;
   b. demonstrated the interlocking nature and complexity of construction management decision made within a construction company;
   c. enhancing their knowledge of decision made on bids, labour allocation and project managers allocation, particularly for those with a civil engineering background;
   d. improved awareness of team work, communication and leadership skills, particularly by team leaders.
However, MERIT2 did not meet the participants' needs in enhancing their knowledge of decisions made on overhead allocation and cash distribution and borrowings, resulting in poor knowledge gained in other areas of construction management promoted by MERIT2.

5.3 SURVEYED SAMPLE 2: MERIT2 AS AN EDUCATIONAL TOOL

A sample of 23 (part/full time) postgraduate students undertaking a Master Degree in Construction Management at Loughborough University, were surveyed. Taking part in MERIT2 is part of their academic requirement to support the conventional way of teaching in Construction Management. The main aim of this survey was to:

- Compare the effectiveness MERIT2 as an educational tool to support the conventional method of teaching construction management, with its use as CAL tool to promote CPD within the construction industry; and
- Seek evidence of the effectiveness of MERIT2 through participants’ knowledge improvement in areas of knowledge targeted by this simulation game.

To achieve these aims, the following were surveyed:

- Participants’ opinion of the quality of support material, their knowledge improved upon decisions made and their value and enjoyment of the simulation game. The selected population ‘Sample 2’, is much smaller in size, when compared to sample 1 (section 5.2). This may not provide solid evidence when comparing the results obtained from both samples, but may help define the participants’ pattern of behaviour, and in turn draw some comparisons. Therefore, a similar approach of analysis to section 5.2 is undertaken to analyse the participants’ responses;
- Pre-task and post-task knowledge improvement surveys, to test the participants' knowledge in areas of construction management, before and after taking part in MERIT2;
- Participants’ confidence development, to investigate the gain in participants’ confidence after each round of the simulation game.
The rest of this section describes these surveys and provides a summary of the results generated.

5.3.1 Participants' opinion of MERIT2
The same questionnaire used to survey sample 1 (section 5.2) and enclosed in (Appendix D) was used to investigate the participants' opinion of the simulation game. This section presents a summary of the results generated from this survey:

i. Analysis of attributes
- 39% of the population sample were of ages between 22-25, while 61% were older than 25 years;
- All participants held B.Sc. qualifications in Civil Engineering, and all took part in MERIT2 for the first time;
- 17% of the participants had mainly worked for consultants and 83% had worked for contractors;
- 65% had 3 or less years of experience and 35% had more than 3 years of experience.

ii. Participants' opinion of MERIT2
Adopting a similar approach to section 5.2, participants' opinions (expressed in scores of 1(low) to 5(high)) on various aspects of the simulation game were analysed. The average scores given by participants to different aspects of the simulation game, were graphically presented and compared with the average scores given by the participants from the surveyed sample 1 (section 5.2). Figure 5.1 (a, b, c, d) shows a plot of these results, and the following observations are made:

- Scores given to the introductory stage of the simulation game by both population samples, fall in the 'good' region. However, the average score given by the postgraduate participants to the introduction and briefing of the simulation game were slightly higher than those given by participants from Sample 1. It can also be observed
that scores given to the information in the manual and for filling in the decision forms are similar for both surveyed samples.

- Scores of more than three are given by the postgraduate students to knowledge improvement upon bidding for jobs, labour allocation and project manager allocation. These scores fall in the 'fair-good' region and are higher than those given by sample B. However, similar scores are given by both samples for knowledge improved upon decision on overhead allocation and cash distribution borrowings, indicating poor knowledge improvement.

- The results for knowledge improvement in other areas of construction management given by both samples fall in the 'poor' region, and showing similar pattern of scoring.

- Scores obtained from both surveys for the value and enjoyment of the simulation game fall in the 'good' region. Although similar pattern of scorings can be observed from both surveys, the results reported by the postgraduate students were slightly higher.

In summary, these results illustrate similar pattern of responses given by both samples to the different aspects of the simulation game. Such observations reinforce the conclusions drawn from the study in section 5.2, highlighting the strengths and weaknesses of the MERIT2 simulation game with reference to the participants' response.

### iii. Participants' responses vs background

The results of a One Way Anova Test shows that there is no significant difference in the mean scores given by different groups of participants, indicating that these score present the whole population sample. Values of H (Kruskall-Wallis statistics) and the corresponding significance indicate that there is no significant difference in the scores given by different groups of participants to all aspects of the simulation game.

Further analysis to the relevance of the simulation game revealed that 70% of the sample population were in favour of the simulation game as a tool that is relevant to improving their professional ability. The results also showed that 39% of the participants found the simulation game relevant to their existing practical experience. Sixty five percent of the
participants showed interest in taking part in MERIT2 again. The Chi-square analysis showed that, these were mainly participants with < 3 years of experience.

In summary, the results of this survey indicate that participants' response to different aspects of the simulation game did not depend on their background. This could be due to the fact that all participants were Civil Engineers with BSc level of education. The participants' background is also believed to have influenced their response to the relevance of the simulation game. A higher percentage of participants from Sample2, indicated that MERIT2 is relevant to their existing and practical experience, than those reported by sample1. The results also reinforced previous findings indicating that less experienced participants are more motivated to take part in the simulation game again.

<table>
<thead>
<tr>
<th>Poor</th>
<th>Fair</th>
<th>V Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Introduction and briefing to MERIT2

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
</table>

Quality of information given in the manual

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

Information given for filling in the decision forms

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

a. Average scores to the introductory stage of MERIT2
b. Average scores for knowledge improvement as a result of the decision making process
Poor | Fair | V Good
--- | --- | ---
Organisational theory
1 | 2 | 3 | 4 | 5
Planning
1 | 2 | 3 | 4 | 5
Forecasting
1 | 2 | 3 | 4 | 5
Financial management
1 | 2 | 3 | 4 | 5
Marketing
1 | 2 | 3 | 4 | 5
Group behaviour
1 | 2 | 3 | 4 | 5
Communication
1 | 2 | 3 | 4 | 5
Competitive bidding
1 | 2 | 3 | 4 | 5

c. Average scores for knowledge improvement in other areas of construction management
Value of MERIT2 as a learning medium

Value to demonstrate the inter-related nature of construction decisions

Value to encourage team work

Value to promote interest in areas outside participants' practical experience

Enjoyment of MERIT2

d Average scores given to participant's value and enjoyment of MERIT2

Figure 5.1 Comparison between the average scores given by participants from surveyed samples 1 and 2
5.3.2 Knowledge testing

Within the scope of this research, participants' responses to different aspects of the simulation game, expressed in scores, do not provide sufficient measures of the effectiveness of MERIT2. Therefore, a knowledge testing questionnaire was constructed (see Appendix D), and distributed to test the participants' knowledge before and after taking part in MERIT2. The main aim of this survey was to investigate whether taking part in MERIT2 improved the participants' knowledge of the:

- interlocking nature of overhead allocation, cash distribution and borrowing.
- interlocking nature the construction decisions within the simulated construction company.

To help achieve these aims, each participant was asked to answer a set of questions 'independently' before taking part in MERIT2 to assess their knowledge of different areas targeted by the simulation game, before taking part in it. The same assessment test was carried out to test the participants' knowledge after taking part in the final round of MERIT2. Table 5.32 shows a list of the areas in which participants' knowledge was tested (column 1), the total mark given to each section of the test presented in percentages (column 2), the results of the pre/post task tests presented as a percentage of the total mark given to each section (columns 3 and 4).

The results of the pre-task tests indicate poor knowledge in the areas questioned. This is indicated by an average population score of less than 50% given to each section of the test. However, the results of the post task test showed a remarkable increase in these marks, raising the overall percentage of scores from 46% before taking part in the simulation game to 76% afterwards. This indicates that the population knowledge has increased by 30% overall, reflecting the educational effectiveness of the simulation game to promote learning in construction management.
<table>
<thead>
<tr>
<th>Knowledge of</th>
<th>Total mark</th>
<th>Pre-task test</th>
<th>Post-task test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1: cash distribution and</td>
<td>35%</td>
<td>15%</td>
<td>25%</td>
</tr>
<tr>
<td>borrowings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part 2: overhead allocation</td>
<td>20%</td>
<td>5%</td>
<td>15%</td>
</tr>
<tr>
<td>Part 3: decisions on bids</td>
<td>10%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Part 4: project managers allocation</td>
<td>10%</td>
<td>3%</td>
<td>6%</td>
</tr>
<tr>
<td>Part 5: decisions on bids</td>
<td>25%</td>
<td>18%</td>
<td>25%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>46%</td>
<td>76%</td>
</tr>
</tbody>
</table>

Table 5.32: Summary of results obtained from the pre-task and post-task knowledge improvement test

5.3.3 Confidence development survey

The aim of this survey is to further investigate whether participants’ knowledge and confidence upon different aspects of the simulation game, improved after each round of MERIT2. To assist with this enquiry, a questionnaire survey (shown in Appendix D) was constructed and distributed after each round of the simulation game. Table 5.33 column 1 presents a list of the questions asked in relation of knowledge gained, and column 2 classified the level of confidence that students feel they have achieved after taking part in each round of MERIT2. Table 5.33 shows a summary of the data collected from this survey presented as percentages of the population opinion. Figure 5.2 shows a graphical presentation of these results, and the following observations are made:
• participants' confidence in understanding the information presented in the manual did not increase with the number of round;

• participants developed greater confidence in understanding the nature of decisions made on bids and labour allocation, and remained highly confident of making decisions on project managers; and

• participants gained some confidence in decisions made on overhead allocation and cash distribution and borrowings, this confidence however, reduced after each round
a. Understanding information in the manual

b. Decisions on bids

c. Decisions on labour allocation

d. Decisions on Project Manager
e. Decision on overhead allocation

f. Cash distribution and borrowing

g. Team work

h. Interlocking nature of decisions made
i. Understanding the output report

j. Making the next set of decisions

Figure 5.2: Participants’ confidence development after each round of the simulation game
<table>
<thead>
<tr>
<th>Areas of知识</th>
<th>Confidence</th>
<th>Round 1</th>
<th>Round 2</th>
<th>Round 3</th>
<th>Round 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding the information</td>
<td>v. confident</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>confident</td>
<td>31</td>
<td>68</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>no confidence</td>
<td>69</td>
<td>27</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Decisions on bids</td>
<td>v. confident</td>
<td>4</td>
<td>9</td>
<td>40</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>confident</td>
<td>23</td>
<td>55</td>
<td>50</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>no confidence</td>
<td>71</td>
<td>36</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>Making decisions on labour allocation</td>
<td>v. confident</td>
<td>14</td>
<td>27</td>
<td>50</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>confident</td>
<td>41</td>
<td>55</td>
<td>40</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>no confidence</td>
<td>45</td>
<td>18</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Making decisions on project managers allocation</td>
<td>v. confident</td>
<td>78</td>
<td>82</td>
<td>80</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>confident</td>
<td>22</td>
<td>18</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Making decisions on overhead allocation</td>
<td>v. confident</td>
<td>27</td>
<td>50</td>
<td>58</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>confident</td>
<td>73</td>
<td>45</td>
<td>30</td>
<td>56</td>
</tr>
<tr>
<td>Making decisions on cash distribution and borrowings</td>
<td>v. confident</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>confident</td>
<td>18</td>
<td>50</td>
<td>28</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>no confidence</td>
<td>77</td>
<td>35</td>
<td>63</td>
<td>71</td>
</tr>
<tr>
<td>working as a team</td>
<td>v. confident</td>
<td>23</td>
<td>32</td>
<td>40</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>confident</td>
<td>59</td>
<td>54</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>no confidence</td>
<td>18</td>
<td>14</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>understanding the interlocking nature of decisions</td>
<td>v. confident</td>
<td>18</td>
<td>14</td>
<td>20</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>confident</td>
<td>27</td>
<td>50</td>
<td>70</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>no confidence</td>
<td>55</td>
<td>36</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>understanding the output report</td>
<td>v. confident</td>
<td>9</td>
<td>9</td>
<td>20</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>confident</td>
<td>36</td>
<td>59</td>
<td>70</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>no confidence</td>
<td>55</td>
<td>32</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>making the next set of decisions</td>
<td>v. confident</td>
<td>59</td>
<td>9</td>
<td>40</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>confident</td>
<td>36</td>
<td>68</td>
<td>50</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>no confidence</td>
<td>5</td>
<td>23</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 5.33: Participants' confidence development after each round of the simulation game, presented in percentages.
5.3.4 Main findings
The results of the survey sample 2 shows that, MERIT2 generally gained a better response to its value as an educational medium by students undertaking their postgraduate course in construction management than those given to its value to promote CPD by participants from industry. Also that MERIT2 is valued as a CAL tool to promote learning in construction management, however its effectiveness in reaching its targeted aims and objectives could be improved. These conclusions were reached as a result of a number of observations:

- Students undertaking their postgraduate courses showed more satisfaction with the introduction and briefing of MERIT2. This is credited to the environment of running MERIT2 and the direct lines of communications between the students and the game controller. This can be considered a contributing factor to their higher responses to knowledge improved upon decisions on bids, project managers’ allocation and labour allocation.

- The quality of information given in the manual gained a low response by both population samples, similar behaviour was observed from responses given to knowledge improved upon decision made on overhead allocation and decisions on cash distribution and borrowings. Students’ responses from sample 2 to knowledge improved in other areas of construction management were generally higher than those given by the CPD participants in sample 1. However, responses given by both samples generally indicated less than fair knowledge improvement.

- Both population samples enjoyed and appreciated the value of MERIT2, although higher responses were given by the student population sample.

- The results of the pre-task and post task questionnaire surveys showed that taking part in MERIT2 improved the participants knowledge in principal areas of construction management targeted by the simulation game.

- The results of the confidence development survey, showed that MERIT2 improved the participants’ confidence in knowledge gained upon decisions on bids, labour allocation.
and project managers’ allocation after each round of the simulation game. However, less confidence was developed by participants after each round of the simulation game on decision made on overhead allocation and cash distribution and borrowing. Participants’ confidence on knowledge gained over the interlocking nature of decisions made was also reduced after each round.

- Little confidence was gained on the understanding of the information given in the manual.
- Participants’ confidence of team work increased after each round of the simulation game.

5.4 CONCLUSIONS
The main concern of this chapter was to investigate the effectiveness of MERIT2 as a CAL tool to promote learning in construction management. The results of this investigation led to the following conclusions:

1. The introduction and briefing of the simulation game is not efficient, particularly when the exchange of information before and while taking part in MERIT2 are postal.
2. The quality of support material given to individuals taking part in MERIT2, must cater for participants’ background, particularly their existing level of knowledge and experience of the areas introduced.
3. Participants’ knowledge improvement, depends on their understanding of the interactive nature of the decisions made to fill in the decision forms. Failure to illustrate (either, by the simulation game controller, or by the feedback from the reports) the consequences of the decisions made, results in failure to reflect and reinforce the knowledge gained.
4. Taking part in the simulation game once, gives an appreciation of the value of the simulation game. However, taking part once may not be sufficient to reflects the complicated nature of the simulation game.
Based on the above conclusions derived from the study of this chapter, the following recommendations can be made to improve the effectiveness of MERIT2:

- Better introduction and briefing to MERIT2 can be made, particularly for those who are based in industry.
- The quality of information given in the manual can be improved.
- A trial session can be introduced to practice the implication of decisions made and develop a better understanding of interlocking nature of these decision.
- The structure of the simulation game can be improved by providing feedback on the consequences of decisions made and clarifying the data output of the generated reports.
CHAPTER SIX

MULTIMEDIA IN CONSTRUCTION

6.1 INTRODUCTION

6.2 MULTIMEDIA (DEFINITIONS AND BACKGROUND)
   6.2.1 Interactivity
   6.2.2 Interactive CAL multimedia courseware

6.3 MULTIMEDIA CAPABILITIES AND LIMITATIONS
   6.3.1 Multimedia capabilities
   6.3.2 Multimedia limitations

6.4 MULTIMEDIA APPLICATIONS IN HIGHER EDUCATION
   6.4.1 Classification of multimedia courseware
   6.4.2 Multimedia applications in engineering education

6.5 MULTIMEDIA AND LEARNING IN CONSTRUCTION

6.6 SUMMARY
CHAPTER 6

MULTIMEDIA IN CONSTRUCTION

6.1 INTRODUCTION

'Multimedia' is another example of CAL, which uses a relatively new technology that integrates a variety of media in a single electronic medium, and provides links to ideas in a non linear format. As a rapidly developing technology, innovations in both hardware and software appear continuously, so that a widely accepted definition of multimedia remains elusive.

This chapter begins by seeking a definition of the term ‘multimedia’ and provides an overview of the types of computer based multimedia tools available, placing these in a context in higher education. The main focus of this chapter is to set a foundation for understanding how multimedia can become an effective teaching and learning tool within the construction domain in higher education giving examples of how and where, multimedia can play an effective role.

6.2 MULTIMEDIA (DEFINITIONS AND BACKGROUND)

The term Multimedia is derived from the Latin, ‘multi’, (many), and ‘media’, (ways of presenting information). The many ways one can present information on an audio-visual computer include text, pictures (both photo and illustrations), sounds, animation (such as moving diagrams) and full-motion video (Pinheiro, 1998, Coorrough, 1998).

In the Oxford dictionary (1996), the word ‘media’ is itself merely the plural of ‘medium’. Medium is an intervening substance through which impressions are conveyed to senses. According to Barker and Tucker (1990) and Grosky and Jain et al (1997), the term multimedia is a contradiction that is being used to mean a multiple of mediums.

Twenty five years ago, the technology needed to bind individual media together simply did not exist. There was no way of combining the information from workbooks, sounds from audio tapes, and images from slides and film strips. Today,
however, the multimedia environment is dramatically different. Electronic technology provides a single medium with the power to integrate diverse types of information. So the first stage of identifying modern multimedia is to focus on its power to draw together different forms of communication, integrating them within a digital environment, and providing access to stored information using computer systems which are fast, friendly and, above all, interactive. One of the reasons for the failure of multi-media in the classroom in the 1970s, was the way it was being presented. Although excellent in themselves, each of the elements of the multimedia was delivered independently. This fragmentation was however unavoidable with the technology then available (Feldman, 1990, Hofstetter, and Fox, 1997).

In the 1980s the term Multimedia was being used to describe a package of information presented as a combination of forms: text, audio cassette, audio video tape and so on. For the 1990s, with the arrival of personal computers possessing audio and video capability, the term multimedia has taken on a whole new meaning. This is because the personal computer makes it possible to access and manage a wide variety of media in ways which were previously impossible (Barker and Tucker, 1990, Blattner and Dannenberg, 1992).

To avoid confusion between the terms hypertext, hypermedia and multimedia, these terms need to be identified. The term hypertext refers to text whose interconnectedness is made explicit and navigable. The interconnectedness is defined by the computer (or even by the user), in the form of links between words or phrases or 'chunks' of the document. They are made navigable by defining those chunks as 'buttons' or 'hot links', such that when the button is activated (e.g. by clicking on it with a mouse) the connected word or phrase or chunk appears. The chunks can also be audio or video material, hence the extension of the idea to hypermedia. Hypermedia presents the ability to move through information consequentially, and frees the users from linear movement through information, such as going from page to page in a textbook. Multimedia is defined as being a term that refers to workstations that supports text, graphic displays, audio-visual materials stored on CD-ROM or hard disk (Laurillard, 1993, Pinheiro, 1998). According to Coorough
‘multimedia gives life to flat information, it encourages users to embrace, internalise, and glean more information from multiple directions. The users of multimedia applications have an opportunity to read about information and can also see it and hear it’. 

The transition from traditional CAL to multimedia, was addressed by Reisman and Carr (1991) who defined the significant characteristics of multimedia as being

- Increased use of pictorial and audio material;
- Integration of instruction with other applications;
- Increased learner control;
- Use of the touch-sensitive screen for input;
- Increased use of simulation and problem solving modes; and
- Authoring and presentation system as media managers.

The basic requirement for developing or running a multimedia application, is a powerful personal computer with a high resolution colour screen, a sound card, speakers, and a CD-ROM (compact disk-read only memory) drive for storage. The storage requirement for multimedia which includes sound, pictures, and particularly video clips is much greater than that of text. This will therefore allow for the integration of data, text, images and sound within a single digital information environment, which in return addresses the full capacity of multimedia (Furht, 1998).

6.2.1 Interactivity

(Feldman, 1990, Gibbins, 1992) addressed interactively as a key feature of successful multimedia, in an information system as it gives the user influence over access to the information and a degree of control over the outcomes of the system. In practice, this usually means that, in one form or another, the system presents the user with choices. The decisions taken influence the path the user follows through the information. Each decision point is rather like a cross-roads. After reading the signpost, the user moves off in the direction of his/her choice until he/she arrives at the next cross-roads. In a digital information system, multi-media or otherwise, the ‘cross-roads’ and the resulting network of possible pathways are created by a
A computer program designed to control and moderate the user's access to the information. Interactivity can mean a lot more than Hypertext, and can allow learning by discovery, using hypertext the user clicks on 'hot words' in the text with the mouse, and then related information such as an article or picture is shown on the screen. Interactivity allows the user to 'navigate' through information in many different ways (Sueann and Hooper, 1990, Cawkell, 1996). Heath (1995) disagrees with how multimedia makers are using the terminology of 'interaction' without any clarification. Heath argued that a genuinely interactive exchange is only possible between two people.

The Collins English Dictionary (1993), contains two definitions of interactive, 'allowing or relating to continuous two way transfer of information between a user and central point of communication system', (e.g. Computer; two or more persons) or 'forces acting upon or in close relation to each other'.

Although literature reveals a dispute over the definitions of the term 'interactive', it also reveals a constant strand over the last twenty years however of clear benefits of interactivity indicating that people are educated and trained more effectively if they are able to interact with the educational or training medium. This is a gross generalisation, as interactivity will be more effective in some circumstances than in others. However, interactivity is an important ingredient in teaching and learning. This should mean that multimedia is an obvious candidate for both training and educational applications. Not only does it offer interactivity but it also brings a range of different media to bear on the issue of clarifying, communicating and informing (Falk and Carlson, 1995).

Laurillard (1993) defined interactivity as being used to differentiate computer-based learning from other methods by virtue of computer's capability to be programmed to change its behaviour according to the learner's input. Laurillard's definition is referred to in this research when the term interactive is used.
6.2.2 Interactive CAL multimedia courseware

Guided by Laurillards’ definition of interactivity, a simple definition for ‘interactive multimedia courseware can be introduced as being, ‘the capability of the courseware to change its behaviour (response) according to the learner’s input (stimulus), such stimulus response relationship is enriched with more than one form of media such as text, graphic, sound and audio-visual material’. The development of a multimedia CAL exercise in Chapter 7, is guided by this definition.

6.3 MULTIMEDIA CAPABILITIES AND LIMITATIONS

This section describes the literature reviewed to identify the main capabilities and limitation of multimedia CAL tools in higher education as follows:

6.3.1 Multimedia capabilities

- From traditional teaching to new technology

According to Falk and Carlson (1995), multimedia has the potential not only to improve current educational practices but also to revolutionise the way that higher education is provided. Multimedia represents a potentially powerful technology for higher education that could, with proper use, increase productivity immensely. Multimedia can make lectures more interesting and effective and, more so than books, can provide varied information to students outside of class. Having the skills to use multimedia can empower students to learn in new ways and to develop higher-order cognitive skills.

However, Bagui (1998) argues that, there is a distinct advantage for the use of multimedia over the traditional books or computer assisted learning. Even the most illustrative text books cannot make use of sound, animation, or video clips. CAL, has also been unable to make use of sound, which has minimised the introduction of CAL into those areas which are heavily sound oriented, such as languages and music. Therefore, the greatest benefit from multimedia may be supporting more flexible methods of learning.
• **Enhancing students learning**

The importance of pictures as an educationally useful medium is stressed by Barker (1989) "Indeed, it is now quite well established that images and pictorial data play an important role in (1) determining the way in which individuals perceive their external environment, (2) facilitating mechanisms of memory and recall, and (3) influencing the efficiency with which people are able to communicate with each other with computers".

Literature shows that Multimedia courseware facilitates active learning. This technology offers the means of ensuring the desired learning activities are performed. It also can be designed so that it provides online feedback to the students, so that they can assess their own progress and understanding. Multimedia technology offers the opportunity to simulate reality and therefore can facilitate experiential learning (Davies and Crowther, 1995, Nulden and Scheepers 1999).

Bagui (1998), stressed that multimedia facilitates different forms of learning such as exploration and discovery, rather than mere instruction. It enriches the learning process by providing the learner with a set of tools, enabling them to explore the learning environment, and navigate through information in a variety of ways. Multimedia provides the opportunity for vastly enhanced simulation, adding high degree of realism to learning situations and making learning much more exciting.

• **Efficiency gains**

Crowther and Davies (1995) argued that, using Multimedia courseware and thereby reducing the amount of educator -learners contact time appears to offer the scope for significant efficiency savings. Fletcher (1989,1990) and Khalili and Shashaani (1994), recorded 88% savings in learning time with computerised instruction. Nulden and Scheepers (1999), argued that, there is possibly an opportunity to replace some traditional teaching with multimedia courseware. Lecturing to large groups of students may not provide a good learning experience and multimedia may offer a solution to the problems of large students numbers.
• **Motivation**

The motivational function of the computer has been considered an important factor of many computer based instructional programs. Although Clark (1994) claims that media does not motivate learning, research done by Yang (1996), shows that intrinsic features of computer such as feedback, sound, active interaction, and individualisation are more likely to motivate students to learn than any other media. Multimedia enhances traditional text-only interfaces and yields measurable benefits by gaining and holding attention and interest, which inevitably fosters improved information retention (Vaughan, 1993).

• **Learning styles**

According to Paolucci (1998), a positive relationship exists between the structuring of knowledge domain, as reflected by multimedia courseware, and positive learning performance. Chou and Lin (1998) however, stressed that there is no interaction between many types of multimedia and cognitive styles. Castelli and Colazzo et al (1998) measured the performance people and strongly argued that ‘multimedia will allow individualised learning catering for individual learning styles of students’. Rasmussen and Shivers (1998) stated that there is a significant interaction between levels of learner control and the processing dimensions of learning styles.

Therefore, the interactive capabilities of multimedia courseware means that the courseware can adapt to the specific learning abilities and styles of the students (Crowther and Davies 1995). Chapter 7 takes advantage of the capabilities of multimedia tools mentioned in this section, to produce a multimedia exercise for undergraduate quantity surveying students.

**6.3.2 Multimedia limitations**

Davies and Crowther (1995) suggested that multimedia applications have limitations to their use as educational tools, when implemented to enhance the teaching and learning process. Some of these limitations are listed below:
Practical limitations

- Although multimedia courseware is capable of facilitating experiential learning (defined in section 2.3.1), the complexity of a real life situation can never be replicated with total accuracy. Students may become more efficient in interacting with the computer but less able to interact with real people. For example, within the construction discipline, multimedia applications are capable of facilitating different construction processes, however they cannot incorporate real life risks associated with these processes.

- Although students may enjoy a highly entertaining multimedia courseware (for example animation and sound effects), this does not necessarily lead to effective learning.

- Although multimedia courseware has low marginal costs, there are considerable start up costs involved.

- Although multimedia courseware facilitates active learning, it does not mean that the students give enough thoughts to the response given to the courseware.

- A key component of knowledge acquisition is based within the cognitive learning domain, and requires the integration of that new knowledge into the existing framework of knowledge. This integration often needs the active involvement of the educator, but multimedia changes the role of that educator in the learning process. The educator should be responsible for clarifying how the new technology is targeted towards achieving the desired educational aims and objectives.

- Multimedia courseware is focused on the first three levels of the cognitive hierarchy, and some do not even progress far beyond just the first objective (Section 2.5-hierarchy of cognitive development). Such courseware adopts what has been referred to as a drill and practice approach.

Resource implications

Feldman (1990), Hofstetter and Fox (1997) suggested four important factors in all multimedia systems. First, they need a large memory, typically in the order of hundreds of megabytes. Second, specialised and powerful processing technology is needed to handle high volumes of information. Third, in addition to text and numeric output and display, the system has to be capable of delivering both sound and images to required
standards of any given application. The arrival of new multimedia personal computers on the market cater for such technologies, at reasonably low costs depending upon the specification of the system. Alternatively, multimedia upgrade kits can be purchased cheaply to convert an ordinary personal computer into a multimedia computer. According to Staley (1995), these costs are not a major limiting factors to the use of multimedia in Universities. The problem is more likely to be space. Access to such computers is always a problem. This supports Feldmans’ fourth factor which highlights the importance of having a rich and complex information environment which is worthless unless users can easily find their way around it, locating and accessing the information they require. One way of insuring such access, is to provide appropriate networking connections.

These limitations will be taken into consideration when assessing the effectiveness of QSMM in Chapter 7. The following section provides a review to the use of such multimedia technology in higher education.

6.4 MULTIMEDIA APPLICATIONS IN HIGHER EDUCATION

Literature shows Multimedia applications share a basic conceptual framework, which has five principal components, that provide a useful guide for multimedia developers, these are:

- identifying the educational context of the material produced within the application domain, and defining the application’s general and specific objectives;
- determining which data will be included, how it will be conveyed, and what type of hardware and software will be used;
- acquiring, classifying, organising and storing the data;
- designing and developing the application, using either commercially available or custom-made multimedia authoring tools, and
- implementing, testing and refining the application.

This process is similar to the development of any CAL tools, and was referred to in the framework developed in section 3.3.2. According to (Miller, 1995), the development of multimedia applications offers three special challenges as described below:

First, an effective multimedia application requires a well-developed theme, proper data organisation and balanced visual design to avoid becoming a meaningless potpourri of information. The data must be carefully blended and choreographed to present the application’s theme coherently.

Secondly, existing multimedia technologies have made great progress on their output. It is however, very easy to sacrifice substance in favour of material that is stylish, but empty in concept. This results in applications that never meet their intended goals.

Third, interactive multimedia applications allow the user to explore the data in a number of ways, from a sequential presentation guided by the designer to random exploratory browsing. Taking advantage of this in a coherent way requires special consideration by the developer.

These point will be taken into consideration in the study undertaken in Chapter 7.

6.4.1 Classification of multimedia courseware

The existing multimedia courseware available in higher education covers a wide range of subject areas within various domains such as, engineering, science and social science. The importance and intensity of using multimedia effects can vary from one domain to or other. For example, multimedia courseware for learning languages rely heavily on the use of sound, interactive text (where students type in their text), and images. Some of these may intensely use sound and are highly interactive. Such courseware provide a good example of interactive multimedia, which forms a stimulus response relationship and serve the needs of that particular domain. Other types of multimedia courseware are those that provide response to 'pressing buttons' type of stimulus, and examples of this is the courseware developed to improve study skills.

This type of courseware consists of images and diagrams, but is not interactive, yet it serves its purpose. Other types of multimedia courseware can be generic. This type allows learners to interact and simulate a new situation to which the computer will give a response. It will also allow for the educator to interact with the courseware to set a new situation for learners to simulate.
Listed below are examples of the functionality different CAL media viewed in literature:

a. Hypermedia courseware. This type acts as an instructor or educator, it provides different levels of information. This student is a passive learner and simulates this courseware by clicking on different choices on the screen. Such courseware can be used as an additional source of information to aid teaching.

b. Interactive multimedia courseware. This type vary in their degree of interactively, which can be classified as follows:

- Allowing for learners' interaction, and providing a controlled learning situation. The form of interaction is directed by the courseware, where the students have to type in certain text or animate certain object on the screen to be able to move to different level of information, i.e., providing a stimulus response situation.

- Assessment tools, producing a stimulus response situations and allowing the students to reinforce their learning experience.

- A more flexible environment that allows the students produce a new situation create their own problems and simulate new responses. This provides a self teaching situation.

- Another type of multimedia courseware, is more generic, where it can provide a situation of the educator to have more control over the teaching process, by being able to interact with the courseware and create a new problem or situation, and for the students to simulate the new responses.

Within the context of this research, the term multimedia is addressed by the knowledge and information captured in multiple media such as, text, graphics, images, sound and video. This is illustrated by the study in Chapter 7.

6.4.2 Multimedia applications in engineering education

The Teaching and Learning Programme (TLTP) has generated a number of multimedia projects within the engineering discipline, some of which were developed for use on foundation courses. Example include: MathsWise project for engineering mathematics, INTERACT (Interactive Engineering Teaching and Learning Project), the MATTER project (for material science), used in Aeronotical, Manufacturing, Chemical and
Mechanical engineering; the QUEST for Electrical engineering; and ECorr project for Chemical engineering (TLTP, 1996).

For construction engineering, two projects have been generated by the TLTP:

- **COMPACT** designed for the Civil and Structural Engineering degree courses (although undergraduates in Architecture and Building degree courses also benefit). The subject matter covered by the courseware to encompass most, of the structures and materials syllabuses taught in university Civil Engineering departments in the UK. The topics covered are: (Cement and Cementitious Materials, Concrete Mix Design, Properties of Fresh and Hardened Concrete, Basic Design of Reinforced Concrete Structures, Advanced Design of Reinforced Concrete Structures, Design of Pre-cast Concrete Structures, Design of Prestressed Concrete Structures, Conceptual Design of Concrete Structures, Concrete Site Practice, Design of Foundations and Retaining Walls, Drawing and Detailing of Concrete Structures, Design of Concrete Bridges, Formwork and Falsework, Inspection, Maintenance and Repair, Buildability and Failure Modes).

**COMPACT** is a suite of computer-aided learning programs covering 15 topics on concrete technology and the design of concrete structures to EC2, where appropriate. It was produced primarily for undergraduate use, the interactive programs use photos, graphics and videos to present teaching material in an easily absorbed and interesting manner. Several of the modules, particularly those on reinforced concrete design, will also appeal to graduate engineers wishing to familiarise themselves with EC2.

- **GeotechniCAL** (Geotechnical Computer-aided Learning) for Geotechnics.
  (Interactive Tutorials for Basic Geotechnical, Soil-Structure Interaction, Foundation Design, Site Investigation, Simulated Laboratory Tests on Soils)

The development and implementation of multimedia in construction has grown in the recent years. Aminmansour (1994), expressed his views of the multimedia technology in helping the construction industry by demonstrating to workers how to operate a new piece of equipment or simulating different conditions including potentially dangerous ones, before interacting with the equipment for the first time. He also thought of
workers designing and preparing a variety of concrete mixes and studying their properties without using any physical material except the computer. Another was updating workers training for certification in their given field and updating their knowledge periodically with minimal expense. Aminmansour emphasised the value of having on-line access to many resources such as codes, references, and design aids including tables, charts, plots, and other elements, while working on their computer. He also proposed how multimedia can assist with students learning and experimenting with "real world" issues during their college education so that they can be better prepared and productive in a shorter period of time following their graduation. Also, simulating and viewing a certain construction process before even stepping on the job site, or managing storage of equipment and supplies for a job site right on the student's computer.

Since this research was initiated, new areas of research have been created, addressing some the issues raised by Aminmansour (see section 3.2.3). The study in Chapter 7, supports Aminmansour in that 'use of multimedia technology in Civil Engineering and Construction, has the potential to help produce cost effective training tools by avoiding expensive and repetitive procedures which require time, equipment, and other resources. It can also reduce unnecessary risk to personnel and waste materials'.

Vanegas and Baker (1994), grouped Civil Engineering multimedia applications into four categories:

a. Business-development or marketing presentation. Where multimedia can create dynamic presentations of the firm's abilities and successful past work, using photographs of finished projects, video clips of selected events or processes, audio clips of interviews with key people, specifications, plans and as-built drawings, performance records, and other information. Customised presentations can show potential clients the final results-or the time-based evolution-of relevant past projects in a dynamic way.

b. Technical-support systems for project planning and design. Technical reference materials can have greater impact if presented in a multimedia format, which can incorporate data in any media from regulatory agencies past projects, manufacturers, codes, liberties of design details, renderings of potential design
problems and possible solutions, interdisciplinary design co-ordination check lines and many more.

c. Construction documentation. Multimedia applications can document process progress, events and lessons for the corporate memory in a broad, flexible way. For example, in a multimedia framework, constructability knowledge can be developed throughout the life cycle of the project, from both ongoing analysis and actual results.

d. Education training materials and learning environments. Educators can enhance student’s understanding of ‘real’ process and phenomena by using multimedia to better convey real-world experiences in a classroom environment and put learning in context. This aids a deeper exploration of certain topics, while enhancing the communication between instructor and students. This is the focus of the study in Chapter 7.

According to Vanegas and Baker (1994), the breadth of multimedia enables it to incorporate lessons generated in a number of ways, including written reports, details in the field, verbal descriptions, plans and specifications, models and mock-ups, slides of construction details or situations, and videotapes of construction operation. These elements can be combined in electronic constructability manuals that can be queried and manipulated in a number of ways. But the process need not stop there. The manuals themselves become one component within the larger lessons-learned and can later become part of the even broader multimedia system.

Although there is a number of multimedia courseware available for educational purposes in construction, there is still a wide range of construction and civil engineering subjects to be exploited. Particularly those subject areas that rely heavily on visual aids and understanding of construction processes. For example, engineering design (steel and concrete design), where students often find it difficult to design the construction elements, when they do not know what they look like in real life and how they fit when designed and constructed. This difficulty often extends to the theory of structures, and the ability of relating abstract concept to visual element that are vague. Another subject area is Quantity Surveying Measurement, where the students find it difficult to measure quantities of building element that they haven’t seen. However, it
is important to understand how multimedia tools enhance the learning process, to meet specific needs in construction. The following section develops this understanding from literature.

6.5 MULTIMEDIA AND LEARNING IN CONSTRUCTION

Nulden and Scheepers (1999) stressed that, the advancement of multimedia technology provides an opportunity for experiential learning, which is participative, interactive and applied. According to Vanegas and Baker (1994), a key objective of any multimedia application is to enhance the product, process and data-visualisation skills of the people who will use the program. Product-visualisation skills enable an individual to grasp an item’s physical elements at a system and/or constructed-facility levels—for example, the beams, columns and slabs of a prefabricated concrete structural system. Drawings, photos, video and text can help the user to understand both how a project relates to the whole and the object’s measurable attributes at different scales. Process-visualisation skills enable an individual to picture all the tasks, activities and/or processes required to build a civil engineering product, such as a high rise system level. Photos (whether real or computer-generated), video clips and animation of simulated construction operation can help users and define and evaluate specific construction methods. Process-visualisation applications can depict what resources are required, how the resources interact and change over time, how the activities integrate into a whole product and, conversely, how a whole project can be down to its components elements. Accordingly, data-visualisation skills help bring together all types of data and computation required for the project’s design, specifications, costs, duration, production and productivity calculations. Multimedia adds an audio-visual dimension to these data, enhancing an individual’s ability to understand and interpret them, and consequently, supporting better technical-and management level decision making.

Therefore, for optimum benefits to be gained from a multimedia courseware within the construction domain, it essential to consider individuals’ experiential learning styles and how effectively an experience has been interpreted to enhance specific strategies. It is also essential to consider the dimensions in which individuals think. As suggested in Section 2.4.2, where people differ in their dimensions of thinking in two ways.
firstly, the ‘wholist-analytic dimension’ (where learners see the whole view of an experience or see things in parts); and secondly, the ‘verbal-imagery’ dimension (where learners are outgoing and verbal or think in mental pictures or images). This study proposes that multimedia CAL is particularly relevant to improving individuals’ imagery style.

Dale (1969) produced a cone of experience that illustrates how the transformation from concrete experience mode to an abstract mode, occurs using different media methods, Figure 6.1. Dale’s model starts with learners as participants in actual experience, then moves to learners as observers of an actual event, to learners as observers of mediated events (events presented through some medium), and finally to learners observing symbols that represent events (Source: Heinich et al, 1989).

Dale contended that, learners could make profitable use of more abstract instructional activities to the extent that they had built up a stock of more concrete experiences to give meaning to more abstract representations of reality. However, if learners do not have the requisite experiential background and knowledge to accommodate these verbal symbols, the time saved in presentation will be time lost in learning.

Literature also reveals that visual demonstrations of real life situation, can assist in developing or shaping the imagery learning style (Petre and Blackwell, 1999). Fitzgerald and Semrau (1998) however, argued that multimedia provide an equally effective learning environment for learners regardless of their learning differences. According to Rasmussen and Shivers (1998) ‘educators can take advantage of the inherent capabilities of multimedia to assist learners in performing to their highest potential through the development of lessons that accommodate preferences for learning.’ Literature reviewed in Chapter 2 (Lowe, 1992), also showed that novice quantity surveyors are divergers in their style of learning. In which case, images and visual demonstrations such as animation, drawing and video can play a role in shaping this learning strategy. Such conclusions provide an ideal case to test the effectiveness of a multimedia courseware, when developed to suit the educational needs of novice quantity surveyors (Chapter 7).
Abstract

Verbal symbols

Visual symbols

Recording, radio, still pictures

Motion pictures

Television

Exhibits

Field trips

Demonstration

Dramatised experience

Contrived experience

Direct purposeful experience

Figure 6.1 Dale’s cone of experience (source, Heinich et al 1989)
A number of studies from literature attempt to define a relationship between the individuals learning styles and navigation paths within hypermedia and multimedia systems, (Horney, 1993, Misanchuk and Schwier, 1992, Nelson et al, 1993, Orey and Nelson, 1994, and Andris, 1996). These areas of research highlight the importance of designing the level of interaction within these tools to promote effective leaning. Such issues are not addressed in this study.

Despite the myths and realities about multimedia, a balance needs to be obtained to provide measures of effective use of multimedia, which can produce effective learning in construction education. Maul and Spotts (1993), Russ (1994) and Rasmussen (1998) suggested that, when using multimedia, learners' expectations must be carefully managed and this has implications for the teaching strategy needed. Motivation will be related to their expectation of being able to successfully work through the multimedia package and also how they benefit from the process. It can therefore be claimed that multimedia CAL tools are capable of providing relevant approached to demonstrate the visualising processes in construction. Also, that these tools can be time and cost effective for learning in construction.

6.6 SUMMARY

Multimedia technology is a valuable tool for integrating a variety of media such as text, graphics, animation images and video clips. Interactive multimedia can facilitate learning by allowing the user to be actively involved in the learning process. When multimedia is not interactive, then the user is defined as a passive learner. Reviewed literature shows that there is a disagreement in thoughts and ideas. Some emphasise the strength of multimedia in its capability of being interactive, while others define this strength through the range of media it provides. Despite the different types of multimedia courseware that have become available and the environments that it runs within, it is the educational needs of both the students and the educator which really sets multimedia courseware. Therefore, by designing the courseware that cater for individuals' needs, the application becomes most effective.
This study ties in with one of the main objectives of this research, addressing the importance of strategic development and implementation of CAL tools that are designed to meet specific needs in construction. While literature reports a lack of multimedia applications to assist teaching quantity surveying measurements, the study in Chapter 7, describes a multimedia CAL exercise that has been strategically developed, and implemented to cater for specific needs for teaching quantity surveying measurements to undergraduate students. A key element that also have contributed to the study in Chapter 7, is the recognition of the divergent learning style of novice quantity surveyors (Chapter 2), which is associated with imagery learning strategies. This suggests that multimedia CAL tools are suitable methods for strengthening these strategies.

Therefore, to test the second hypothesis of this research, Chapter 7 describes in details the approach adopted to develop a multimedia CAL tool to meet the educational needs of novice quantity surveyors, and produces qualitative and quantitative measures of its effectiveness.
CHAPTER SEVEN

‘QSMM’: QUANTITY SURVEYING MEASUREMENTS IN MULTIMEDIA

7.1 INTRODUCTION
7.2 PRE-TASK SURVEYS
7.3 DEVELOPMENT AND IMPLEMENTATION OF QSMM
7.4 EVALUATION OF QSMM
7.5 SUMMARY OF RESULTS
CHAPTER 7

‘QSMM’: QUANTITY SURVEYING MEASUREMENTS IN MULTIMEDIA

7.1 INTRODUCTION

Quantity Surveying is a profession which relates to Civil and Building Engineering and one of its foci is the quantification and measurement process that ultimately underpin the financial integrity and viability of the construction process. Bills of quantities have for many years been the instrument that provides a quantity and financial breakdown of contract prices. The introduction of “design and build” does, to some degree, dispense with a contractual bill of quantities. However, to understand the financial scope, contract bills are often prepared and as a result will still form the backbone of quantity surveying teaching for some years to come.

Over the years, a number of computer packages have been developed to assist quantity surveyors with the process of estimating and producing their bills of quantities. Most of these packages are designed for quantity surveyors who already possess the necessary practical skills and experience and are not designed to perform in an educational role. However, there are no programs that attempt to educate undergraduate quantity surveyors in understanding the measurement rules from first principles, in relation to a standard code of practice, e.g. the SMM7. One of the main stumbling blocks in teaching measurement is that students need to have an understanding of the construction technology process before they can begin to understand the measurement rules that govern the quantification process. This leaves the student facing a problem of not being able to understand the construction process, due to their lack of construction technology knowledge, of the elements that the measurement rules are based upon. This also presents major problems with undergraduate module curriculum, as has been evidenced by educators in the Department of Civil and Building Engineering at Loughborough University.
The main aim of this chapter is to effectively develop a prototype multimedia courseware to assist first year undergraduate quantity surveying students with their understanding of the basic principles of measurement rules. This is achieved by superimposing the measurement rules onto construction technology, to provide better Tutor-Student interaction and to promote an enjoyable way to learn what is a very complex series of procedures. This chapter adopts the relevant aspects proposed by the framework produced in Chapter 3, to effectively develop a CAL tool which will assist the learning process in this area. The following section describes the pre-implementation stage and the surveys undertaken at this stage, to help identify the characteristics of the CAL tool which will promote students learning of the QS measurement rules.

7.2 PRE-TASK SURVEYS

A number of 'pre-task surveys' were undertaken to investigate the need for CAL and to help develop the relevant strategies to meet these needs. These surveys were based on the collective views Quantity Surveying tutors and first year students undertaking their undergraduate degree in quantity surveying, at the Department of Civil and Building Engineering, Loughborough University. Tutors from other universities (University of West of England, Leeds Metropolitan University, and Nottingham Trent University) were also involved in other surveys set to assist with this study. The surveys conducted are described below.

i. The need for CAL. This need was initially raised by the Quantity Surveying tutor, at Loughborough. The educational aims, and objectives were stated, and the desire for a CAL tool to support the learning process in the conventional way was expressed. These desires were translated as a need for a CAL tool which

- Enhances the first year QS students’ learning and understanding of measurement rules.
- Enables the students to relate these rules to a real life situation.
- Enables the students to analyse each element of the bill of measurement into various components that the measurement rules are based upon.
- Improves the students’ imagery skills.
ii. Existing problems. The conventional approach of teaching Quantity Surveying Measurement to the first year undergraduate students (chalk and talk), suggested a surface approach to teaching, which provoked a surface approach to learning. These difficulties were explored by interviewing the subject tutors, who suggested a lack of opportunity to teach the subject in depth and lack of time and resources to promote alternative ways for teaching. One of the major problems expressed was the difference in the students background and their abilities to visualise the building elements and to relate the theory to a real life situation. The recognition of these difficulties led to an investigation of the students’ needs and whether the educators were aware of such needs. Accordingly a survey was conducted to investigate the educator’s views of what they felt the students difficulties were, when introducing two tutorial questions (related to the sub-structure and super structure of a building, and enclosed in Appendix F) taught in the conventional way. To illustrate this, the following actions were taken;

a. A pre-task questionnaire was developed to diagnose the difficulties that may be faced by both, the tutor (when teaching) and the student (when learning). To assist with this investigation, six quantity surveying tutors were contacted at different universities and requested to return the posted questionnaire.

b. Similar questionnaire was distributed to the students who were asked to define their learning difficulties in understanding these tutorial examples. A total of forty students responded to this survey, and identified several difficulties they faced in trying to understand these tutorials. A copy of this questionnaire is enclosed in Appendix G. The results of this survey are summarised in Table 7.1, indicating that:

- Students’ difficulties were mainly related to areas that required three dimensional visualisation (e.g., reading and understanding the drawings given in the question, visualising installation of a damp proof course). The majority of the students reported their difficulties in understanding the measurement rules.
- Tutors’ awareness of their students pre-task difficulties. It is interesting to note that the tutors opinion of what they felt the students faced difficulties were, did not match the perspectives of the students themselves. This is of concern as it
<table>
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<tr>
<th>Problems faced</th>
<th>Students opinions</th>
<th>Tutors' opinions</th>
<th>Agreement in opinions</th>
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<tr>
<td>Reading and understanding the drawings given in the question</td>
<td>This DID present problems</td>
<td>Tutors felt this should NOT have presented problems</td>
<td>None</td>
</tr>
<tr>
<td>Understanding what was required in the question</td>
<td>Students felt they DID understand</td>
<td>Tutors disagreed</td>
<td>None</td>
</tr>
<tr>
<td>Calculating the centre line of a foundation trench</td>
<td>Students felt they DID understand</td>
<td>Tutors disagreed</td>
<td>None</td>
</tr>
<tr>
<td>Visualising back-filling and compacting soil</td>
<td>Students felt they DID understand</td>
<td>Tutors disagreed</td>
<td>None</td>
</tr>
<tr>
<td>Measuring earthwork support</td>
<td>Students felt they DID understand</td>
<td>Tutors disagreed</td>
<td>None</td>
</tr>
<tr>
<td>Measuring wall projections and cavities</td>
<td>Students felt they DID understand</td>
<td>Some tutors agreed</td>
<td>Partial agreement</td>
</tr>
<tr>
<td>Visualising wall ties and types of engineering bricks</td>
<td>Some students felt they DID understand</td>
<td>Some tutors agreed that students understood this aspect</td>
<td>Partial agreement</td>
</tr>
<tr>
<td>Visualising how the quantities of soil are added, deducted and disposed of</td>
<td>Some students felt they DID understand</td>
<td>Some tutors agreed that students understood this aspect</td>
<td>Partial agreement</td>
</tr>
<tr>
<td>Calculating internal and external girths</td>
<td>Some students felt they DID understand</td>
<td>Some tutors agreed that students understood this aspect</td>
<td>Partial agreement</td>
</tr>
<tr>
<td>Visualising installation of damp proof course</td>
<td>This DID present problems</td>
<td>Tutors felt this should NOT have presented problems</td>
<td>None</td>
</tr>
<tr>
<td>Referring SMM7, and understanding the items refereed to</td>
<td>This DID present problems</td>
<td>Tutors also felt this DID present problems</td>
<td>Complete</td>
</tr>
</tbody>
</table>

Table 7.1: Student and tutors awareness of their educational needs in QS

N.B. The population opinion voted for by 50% of the students and tutors, is interpreted as ‘Complete’.

The population opinion voted for by >30-50% of the students and tutors, is interpreted as ‘Partial’.

The population opinion voted for by <30% of the students and tutors, is interpreted as ‘None’.
indicated that lecturers were not aware of their students difficulties in fundamental areas of the exercise.

**ii. Learning styles.** Literature reviewed in Chapter 2 indicated that individuals learning styles change through their professional career. This suggests that educators' style of teaching may differ from the students' style of learning, which may be a factor causing inefficiency in the learning process. To explore this possibility, the following were investigated:

- Students' cognitive styles, and whether one was predominant.
- Tutors cognitive style.
- The match or mismatch between lecturers' preference of students learning style, and that of their own.
- The tutors awareness of the abilities associated with a graduate quantity surveyor.

To assist with this enquiry, the following surveys were undertaken:

**a. Students' cognitive style analysis.** To investigate the students' cognitive styles, Riding's cognitive style analysis (c.s.a) method was adopted (see Chapter 2). Three samples of quantity surveying students were surveyed (40 first year quantity surveying students, 38 of the second year and 35 of the final year students), at the department of Civil and Building Engineering, Loughborough University. Figures 7.1a, b, c. illustrate a summary of these results indicating that:

- 36% of the first year students were verbalisers, 46% imagers and 28% were bimodals. The wholist imagers formed 26% of the population, while the analytic imagers formed 15% of the population.
- 7% of the second year students were verbalisers, 51% were imagers and 42% were bimodals. 22% of the students were wholist imagers, while 21% were analytic imagers.
Figure 7.1 Results of Ridings' Cognitive Style Analysis

(a) Percentage of first year quantity surveying students with different styles

(b) Percentage of second year quantity surveying students with different styles

(c) Percentage of final year quantity surveying students with different styles
• 16% of the final year students were verbalisers, 67% were imagers and 17% were in between. The results also showed that there were 23% analytic imagers, 14% wholist imagers and 30% intermediate imagers.

These results indicate that the students learning styles were not defined during the first year of their degree. The percentage of students with imagery learning style showed slight increase and formed 51%. The imagery style was more defined by the third year students, and dominated almost two thirds of the population (67%). These results validate Kolb’s findings in that students learning styles are shaped by their educational domain (Chapter 2). The results also validate Lowe’s research findings in that the learning styles of a group of students in their undergraduate domain, shaped towards the divergent styles towards the final year of their study. It may be worth noting that there is an overlap in the dimensions of learning and the abilities associated with the divergent styles (Defined by Kolb) and the Imagery styles (defined by Riding).

b. Tutors’ teaching style analysis. Six quantity surveying tutors were selected (from Loughborough and other universities), and the following steps were undertaken:

**Part I:** A survey was conducted to investigate the tutors’ teaching style, using Riding’s Cognitive Style Analysis.

**Part II:** Tutors’ teaching styles preferences were investigated by asking them to identify their one of four different approaches to learning and thinking, adopted by four different hypothetical students (see Riding’s learning styles - Appendix A). Tutors were not aware that the styles of learning adopted by these students corresponded to those defined by Riding, and chose one hypothetical student that they felt would be most comfortable to teach.

**Part III:** Asked the tutors to select one of the four students described in Part II, that they felt had the abilities and qualities associated with a graduate civil engineer and quantity surveyor.

The results of these surveys were summarised and shown in Table 7.2 and the following observations were made:
• Five out of six tutors had a construction background and were assessed as being ‘imagers’.

• All tutors (unknown to them) chose students with learning abilities and performance that matched their own teaching style and performance.

• Five out of six tutors chose the analytic imagery learning style of students as the ones associated with the abilities of graduate novice quantity surveyors. These styles address abilities that are similar to the divergent learning styles defined by Kolb’s LSI (Chapter 2).

It therefore be concluded that although tutors are aware of the nature of skills associated with the graduate quantity surveyors, they feel more comfortable to teach students with styles that match their own style of teaching, even if the latter has been shaped by their profession, as described in section 2.4.1.

iii. Time and cost in the conventional way of teaching. Teaching QS measurement rules in the conventional way, was described by the subject tutors as a process that required the students abilities to visualise various construction processes and relate them to the items described in the code of practice. To produce an equal and effective learning environment required various illustrations, such as showing slides and videos of the different building elements, and arranging site visits. Such processes consume time and incur physical, human costs. When these costs were weighed against the costs incurred by integrating photographic images, animated drawings, video clips and interactive text, it was found that the use of a multimedia CAL tools provided a more economical and practical option. Therefore to effectively produce such a tool, a survey was conducted to explore the conventional approach to teaching and learning in this subject. This survey addressed the time allocated to produce the measurement items for the two tutorial questions presented in Appendix F. The results of this survey showed that:

• Two tutorial sessions (one hour per session) were allocated to aid the students’ learning of these example:

• The time spent by the students to understand each exercise in the traditional way is shown in Table 7.3. On average, 65% of the students had no previous
<table>
<thead>
<tr>
<th>Tutors</th>
<th>Tutors style</th>
<th>Tutors preferred students style of learning</th>
<th>Tutors’ expected style of a graduate quantity surveyors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Analytic-imager</td>
<td>Analytic-Imager</td>
<td>Analytic-Imager</td>
</tr>
<tr>
<td>2</td>
<td>Analytic-imager</td>
<td>Analytic-imager</td>
<td>Analytic-Imager</td>
</tr>
<tr>
<td>3</td>
<td>Analytic-imager</td>
<td>Analytic-imager</td>
<td>Analytic-Imager</td>
</tr>
<tr>
<td>4</td>
<td>Analytic-verbaliser</td>
<td>Analytic-verbaliser</td>
<td>Analytic-Imager</td>
</tr>
<tr>
<td>5</td>
<td>Wholist-imager</td>
<td>Wholist-imager</td>
<td>Analytic-Imager</td>
</tr>
<tr>
<td>6</td>
<td>Wholist-imager</td>
<td>Wholist-imager</td>
<td>Wholist-verbaliser</td>
</tr>
</tbody>
</table>

Table 7.2 Analysis of QS tutors’ teaching styles, their preferences of a students style and expectations of the style of a graduate QS student

<table>
<thead>
<tr>
<th>Students percentage</th>
<th>Time spent to understand each tutorial</th>
<th>Industrial experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>13%</td>
<td>1 30-2hrs</td>
<td>with (1-2) years of construction experience</td>
</tr>
<tr>
<td>22%</td>
<td>3-4hrs</td>
<td>less than one year experience</td>
</tr>
<tr>
<td>55%</td>
<td>4-7hrs</td>
<td>no experience</td>
</tr>
<tr>
<td>10%</td>
<td>2-3hrs</td>
<td>no experience</td>
</tr>
</tbody>
</table>

Table 7.3 The average time spent by the students to understand one of the tutorial example
construction experience and spent 2-7 hours to effectively understand these tutorials. Students with some construction experience spent less time to understand these tutorials.

These results indicate that the time allocated to effectively solve these examples was not enough for most of the students. Students confirmed that their main difficulty was in visualising the different items of the bill of measurement. The following section describes how these conclusions assisted in designing and developing the appropriate CAL tool to aid the learning process of the QS measurement rules.

7.3 DEVELOPMENT AND IMPLEMENTATION OF QSMM

Based on the findings from the pre-task surveys undertaken in section 7.2, it is argued that Multimedia CAL, is an appropriate and cost effective method to support the teaching and learning process in QS measurement. Therefore after careful consideration of the existing tools, ‘Authorware’ version 2.0 was chosen to develop the QSMM (Quantity Surveying Multimedia Measurements) courseware. Authorware, is an icon oriented tool which is capable of developing interactive multimedia courseware. The structure of Authorware works on a series of icons that are displayed as a flowchart, hence loops are represented graphically rather than textually. Its users can create multimedia courseware using the tools available and can also incorporate and edit existing materials. Built in interactions for user feedback include text entry, screen buttons, click/touch areas, movable objects, images and pull down menus. The structure and the environment of QSMM are described below.

i. The structure of QSMM. QSMM was structured to clarify two dimensional visualisation and the interpretations of drawings in relation to real life construction processes. The design of QSMM was also intended to facilitate both Riding’s ‘wholist’ and ‘analytic’ imagery styles and views (Chapter 2), addressing the divergent experiential learning abilities associated with novice quantity surveyors (Chapter 2). In principle, the structure of QSMM was influenced by Dale’s ‘Cone of Experience’ (Chapter 6), to promote a less abstract mode of delivery enriched
with iconic presentations biased towards a more concrete mode of delivery. QSMM was structured to allow for users' interaction and navigation through four menus. The first is an information and help menu. The second provides access to lecture notes, while the third and fourth provide access to two solved tutorial examples, of which one relates to the substructure of a building and the other to the superstructure. These examples aim at guiding the students step by step through a bill of measurements, producing a breakdown of each element of the bill, thus providing users with construction technology information such as drawings, images, animation including video clips of various construction activities where appropriate. QSMM also allows users to navigate through the package by clicking on various links to access explanations and explanatory drawings, some of which are animated to show a sequence of construction operations. When users have familiarised themselves with the problems posed (i.e. the particular sections of a building), they can explore relevant solutions provided within QSMM, by clicking on hot links provided on the items in the bill of quantities, illustrating:

- The rules of measurement on which the quantities are based;
- Specifications;
- Construction sequence.

The use of QSMM was intended to provide an additional tool to learning. To avoid lengthy search of information, the mapping and branching of QSMM consisted of a maximum of three levels of branching, with clear navigational instructions.

**ii. The environment of QSMM.** Once QSMM was developed and ready for use, the following were checked:

- That there was enough space on the departmental server for QSMM to be installed;
- The clarity of images, text and overall information;
- There were clear instructions for the users to access QSMM;
- The speed of running QSMM was acceptable; and
- Enough instructions for the students to start interacting with QSMM.
7.4 EVALUATION OF QSMM

This section describes the methods adopted to evaluate QSMM, and shows a summary of the evaluation results.

i. Efficiency of QSMM.

a. Soundness of academic content. To check the soundness of the academic content, QSMM was first evaluated by four subject specialists at Loughborough and other universities. The returned feedback and comments on the content and ergonomics of QSMM were taken into consideration, to improve its quality and content. QSMM was mounted on the departmental server at Loughborough, and used by 40 students, during a formal tutorial session. Clear instructions were given for running QSMM, and the following surveys were undertaken;

b. Computer experience survey. This survey was undertaken to determine the ease with which the students could use the computer. The results of this survey showed that 5% of the students had poor experience using the computer, while 90% had moderate experience and 5% considered themselves as expert users of the computer. However, it was observed that all the students had no problems logging in and were comfortable with and working through QSMM independently.

c. Usability and mapping of QSMM. To assess the ease with which QSMM was used, the students were asked to give a score from 1 (low) to 5 (high) to the different aspects of the usability of QSMM. A copy of the distributed questionnaire is shown in Appendix G. The summary of these results are shown Figure 7.2 showing that, scores of more than 4 were given to the ease with which students interacted with the courseware, the ease of selecting the menus, clarity of information presented and the combination of media implemented within the courseware. A top score of 5 was given by the students for the overall functionality of the courseware in meeting their objectives. Other aspects of the courseware that showed less satisfaction were then improved by taking the students comments into consideration.
<table>
<thead>
<tr>
<th>Category</th>
<th>Scale</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction with courseware</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Navigation through the courseware</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Selecting of menus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Presentation of diagrams and pictures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Colours used for presentation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncomfortable</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Clarity of information presented</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vague</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Combination of media used (animation and photographs) to produce an effective whole</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not good</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>How would you assess the overall functionally of the courseware in meeting the learning objectives</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 7.2 Evaluation of the efficiency and usability of QSMM
ii. Effectiveness of QSMM. This section describes the approach undertaken to determine the effectiveness of QSMM as a learning tool.

a. Students' attitudes. When QSMM was introduced to the students for the first time, the followings were observed:

- During the first twenty minutes of the tutorial session, QSMM seemed to have raised the students curiosity. Students worked independently by browsing through the menus.
- Having navigated through QSMM, students started to exchange comments amongst themselves creating a relaxed laboratory learning environment.
- Some students expressed a number of constructive criticisms to the tutor.
- Most of the students expressed their satisfaction with QSMM, and showed their willingness to answer the survey questionnaires.
- Students were using QSMM as a guide to solve other examples given by the their tutor in the same session.
- When QSMM was removed from the server after the evaluation session, a noticeable percentage of the students requested access to QSMM until they finished the module.

b. Time vs learning. When students were asked whether QSMM helped them with reducing the time taken to understand a similar problem in the conventional way before QSMM was introduced, the following observations were made,

- 60% of the students said QSMM halved the time spent in understanding the problem and the solution,
- 20% of the students said it did help but were not sure how much time it saved, and
- the rest of the students said it made no difference to their learning time.

c. Problems tackled by QSMM. A post task survey was conducted, to assess the impact that QSMM had on the students' perceived difficulties, and investigate the aspects of QSMM that students found most helpful. Therefore, a break down of the items simulated by QSMM was produced as shown in Table 7 4-column 1, and the
|
|---|---|---|---|---|
| 1. How useful did you find our further explanation of the question by using animation | Made no difference in my knowledge | Interesting way of presenting information | Very helpful | Confusing |
| | 0 | 45% | 55% | 0 |
| 2. How helpful was the package in helping you with understanding the depth of reduced excavation | 15% | 40% | 45% | 0 |
| 3. Calculating the centre line of trench | 40% | 20% | 40% | 0 |
| 4. Demonstrating the backfilling and compacting of materials | 10% | 70% | 20% | 0 |
| 5. How would you classify the demonstration of E.W.S. | 15% | 55% | 25% | 0 |
| 6. Demonstrating the foundation walls, the projection of walls, the cavity in walls, the wall ties and type of bricks used | 10% | 25% | 65% | 0 |
| 7. Demonstrating the quantities of soil deducted, added and disposed off site or on site | 10% | 35% | 55% | 0 |
| 8. Diagrams presenting the calculations of internal girths and external girths | 20% | 50% | 30% | 0 |
| 9. Demonstration of the damp proof course | 20% | 40% | 40% | 0 |
| 10. Demonstration of the different steps of construction that is taken place to fill the foundation | 15% | 35% | 50% | 0 |
| 11. Demonstration of the different parts of the code by referring to each item | 15% | 5% | 80% | 0 |

Table 7.4 Results of the ‘Post task’ questionnaire investigating students’ knowledge improvement as a result of using QSMM
students views were analysed as percentages of the population. It could be detected from these results that the highest percentages of students found QSMM either an interesting way of presenting information or a very helpful tool to aid their learning. None of the students found QSMM confusing to any aspect of their learning. A copy of the questionnaire survey is enclosed in Appendix G.

Students agreed that QSMM was effective in presenting imagery and animated effects, and helped them understand the items related to the SMM7. However, no firm evidence was found to show that students with specific learning styles enjoyed or learned better from QSMM.

7.5 SUMMARY OF FINDINGS
The main findings of the study in this chapter, are summarised as follows:

The approach
- Teaching the QS measurement module in the traditional way, suffered the students different backgrounds and their lack of ability to relate the abstract concepts to real life construction processes. Also, the lecturers lack of resources to provide life demonstrations of such processes, resulted in repetitive explanations of the subject area to different individuals.
- For QSMM to be effectively and efficiently developed, the role of the developer was not confined to the development and implementation stage of QSMM, but also required involvement within the planning and evaluation stage.
- Effective planning for QSMM occurred through clear communications between the quantity surveying educators (lecturers or tutors), and the developer of QSMM and the students.

Pre-task surveys
- Pre-task studies showed that, the conventional method of teaching promoted a surface approach to learning, and the recognition of students’ needs were essential.
Although the QS tutors had defined their own educational needs and goals, and showed interest and motivation for implementing new technology, they were not fully aware of the students educational needs. Also, there was a mismatch between what the educators thought the students difficulties are, and what the actual students difficulties were.

Riding's Learning Style Analysis showed that, although the Quantity Surveying students did not have a defined learning style during their first year in the undergraduate domain, their learning styles seemed to shape as they progressed through their course, with the imagery style dominating by their final year. The comparison of these results agree with Lowe's findings of Kolb's LSI (Chapter 2).

Educators' teaching styles differed from the students learning styles (as expected due to their professional experience). QS tutors preferred students learning styles that matched their own, and were aware of what style of learning they wanted the future graduate quantity surveyors to have.

**Development of QSMM**

- Recognising the students background and their previous experience, assisted in structuring QSMM in such a way, that suits students individual levels and backgrounds.
- Defining aims and objectives, learning styles and transferable skills initially assisted in choosing a suitable authoring tool and assisted the developer in structuring QSMM effectively.
- Defining the relationship between time spent in learning and the integrated media assisted in planning for QSMM to be time and cost effective.

**Evaluation of QSMM**

- The formative evaluation, showed that QSMM was run efficiently on the departmental server and was easily accessed by the students at all times. Also that QSNM was user friendly with more than satisfactory level of mapping and usability.
• The summative evaluation showed that QSMM was most effective to those with verbal dimensions of learning, with little or no previous construction experience. QSMM assisted these with the imagery learning difficulties. It enhanced students learning skills and reduced the time taken to understand complex aspects. However, QSMM did not prove effective for those with an imagery style, and was merely seen as an additional method of learning.

• More than two thirds of the population found all aspects of QSMM an interesting way of presenting information and very helpful. None of the students found QSMM confusing.

It can therefore be concluded that:

• The framework developed in Chapter 3, is useful for adopting strategic approaches to planning, developing and evaluating QSMM.

• QSMM revolutionised the conventional method of teaching quantity surveying measurement, by tackling specific problems to a large groups of student.

• Although QSMM is considered as a second best option to visualising real life construction processes, it added a degree of realism of these processes to students’ learning.

• QSMM was observed to be attention grabbing. Students provided an excellent example of intrinsic motivation by being interested to use QSMM even outside the tutorial hours.

• QSMM proved time-cost effective. It saved at least half of the students’ time spent in learning, in the conventional way.

• Although QSMM was designed to shape the students’ learning styles that match those expected of the novice quantity surveyors (i.e., with imagery style), there was no evidence that a particular learning style had preference to learning with QSMM.

• Although QSMM was not designed to promote a high level of the cognitive hierarchy, it proved effective in meeting specific educational needs.
The QSMM package is an effective and useful tool for teaching quantity surveying measurements from first principles. QSMM’s benefits are in its ability to divide elements of construction into its constituents and show how these fit together in animated sequences. This, in turn, improves students’ wholistic abilities of thinking, their imagery thinking style and also helps improve their analytic style of learning. By doing so, QSMM assists in overcoming the difficulties faced in a traditional lecture-led class room environment.

QSMM has been developed on the assumption that novice quantity surveyors are divergers, with reflective imagination that enables them to translate their concrete experience iconically (i.e., images and diagrams). It was found that students who do need to develop their visualisation skills found QSMM to be effective.

To motivate and stimulate student learning, it is important for educators to be aware of students needs and learning style preferences. The evaluation of QSMM showed that the lecturers were not fully aware of their students needs in certain areas of the exercise. It is important that educators bridge the gaps between their own style of teaching to their students style of learning. Multimedia CAL courseware is a suitable method to assist in this.
CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.1 INTRODUCTION
8.2 DISCUSSION
8.3 CONCLUSIONS OF THE RESEARCH
8.4 LIMITATIONS
8.5 FUTURE RESEARCH
8.6 RECOMMENDATIONS
CHAPTER 8

CONCLUSION

8.1 INTRODUCTION
This research has studied the effectiveness of Computer Assisted Learning in construction and strategic approaches to the development and implementation of CAL tools. Theoretical aspects relating to the hypothesis of this study (presented in Chapter 1) have been derived from literature and tested. This chapter presents a summary of the issues covered by the research and the limitations and main conclusions are presented. Recommendations for future research are also suggested.

8.2 DISCUSSION
The demands of the construction industry for individuals with high levels of cognitive and experiential skills, encourages curricula developers to produce educational tools that meet these demands. The development of new and more useable technology and the wide use of computers in education has prompted the use of Computer Assisted Learning tools within the construction domain. Literature shows that measures of the effectiveness of these tools are often qualitative rather than quantitative, and that no strategic approach is adopted for their effective development and implementation to meet the demands of the construction industry.

Therefore, this research tested the following hypotheses:

i. Qualitative measures are insufficient on their own as measures of the effectiveness of CAL.

ii. CAL is an effective educational tool within the construction domain, when tailored to learners' specific needs and learning styles.

To test these hypotheses, an understanding of effective learning through the use of CAL was essential. Literature however, showed no theories of educational computing. This encouraged the work in Chapter 2 to develop an understanding of the concept of learning and to focus on the study of learning theories that are relevant to learning in
The results of this investigation led to the finding that, 'experience' is a key element to learning in construction and therefore focused on the study of:

- experiential learning theory, to develop an understanding of how learning from experience occurs;
- cognitive learning theory, to develop an understanding of how the information received, from experience, is processed and developed into cognitive and intellectual strategies; and
- behavioural learning theory, to derive measures of changes in behaviour as a result of the learning process.

The study of the experiential learning process led to the finding that, experiential learning can be promoted when learners are given the opportunity to directly interact with the experience 'on the job' or through simulated and interpreted experiences 'off the job'. Also, that the experiential learning theory is a cyclical process which offers a foundation to life long learning, starting with a problem situation, followed by reflection, then forming hypothesis and finally testing these hypothesis in a new situation. Learning can start at any of these stages, depending on the learners' needs and goals. Therefore, for effective development and implementation of educational methods, individuals' needs and goals must be recognised. Literature also showed that each stage of the experiential learning process has associated abilities, forming learning strategies. Recognising the learners' needs, educational tools can be effectively structured and developed to target these strategies. The study also concluded that 'Reflection' is a key element of the experiential learning theory. Reflecting upon experience, will help the lessons gained from the engagement of an experience to be learnt and applied in a new situation.

The study of the cognitive learning theory, helped develop an understanding of how the information received from experience are processed within the individuals' mind, and the development of individuals' intellectual abilities. This study also showed that, the process of cognitive development is associated with the changes of insight in view of the experience gained, highlighting the importance of targeting the educational
needs, through the presentation of instructions or different modes of information. Cognitive theorists, also agree that:

- the cognitive processing of information can be defined in stages generating different abilities and learning strategies;
- an effective educational tool, must keep the tension balanced between, what learners already know, but need to add knowledge to their existing cognitive structure (assimilation), and/or alter their cognitive structures and fit in new objectives (accommodation). The understanding of these terms, makes a clear distinction between the ‘initial learning’ and ‘learning for improvement’, which helps the educational objectives to be effectively delivered;
- the key element to cognitive development, is the development of new ‘mental models’ or changes to old one. Learning does not occur if changes to the mental model fail.

The study of the behavioural theory, addressed learning as a change of behaviour, which results from a stimulus response relationship, providing guidance to monitoring and evaluating CAL tools later on in the research. Accordingly, the behavioural theorists stressed that:

- for learning to be effective it must be reinforced;
- the change in behaviour can be monitored through feedback.

The conclusions derived from these theories guided the direction of the research to examine the use of CAL tools as ‘Stimuli’ that are capable of promoting the experiential learning process. To detect the effectiveness of CAL tools (to promote initial learning or to increase knowledge of already learnt concepts), learners must be given the opportunity to reflect upon the newly learnt concepts and to reinforce the gained experience.

Literature reviewed in Chapter 2 also showed that theorists generally agree that stages associated with the experiential and cognitive learning process, generate different abilities and learning strategies, referred to as learning styles. While the ‘experiential learning styles are associated with the strategies developed from experience, the
cognitive learning styles address the abilities associated with the interpretation of the received information. Therefore, learning styles become highly individual in both direction and process.

This argument guided this study in that, the implementation of CAL tools must address individuals’ needs, goals and learning styles. This was evidenced by previous research reporting that:

- learning is most effective when educational tools are developed to suit individuals’ learning styles, and
- professionals are likely to have different learning styles from novices within the same discipline.

The direction of this research was also influenced by other research reports, indicating that:

- the adaptive competencies and the learning style of novice Civil Engineers are convergent, and that the learning styles of the novice quantity surveyors are divergent;
- learning styles can be shaped and influenced by various factors such as, educational specialisation, profession and work experience;

These findings, directed the research to consider individuals’ learning styles, as a key element to the development of effective educational tools to meet specific needs. This also led to further investigation of the styles of CAL, and their role in enhancing aspects of the learning process.

Chapter 2 also presented the ‘surface’ approach and ‘deep’ approach to learning. While the first features passive learning situations, creating a situation for learners unwilling to engage in a learning situation, the latter features active learning situations, characterised by individuals’ engagement in the learning process, and their understanding and recognition of concepts and relating them to practice. The recognition of these terms, aided the classification of the effectiveness of CAL tools in promoting learning.
The literature review also revealed that effective learning is dependent on the learners' motivation, and considered individuals' motivation an important element for encouraging effective learning. A number of factors influence individuals' motivation, such as: individuals' background (age, experience, level of education, subject of study). This helped the study in Chapter 5, to distinguish between the effectiveness of MERIT2 as a CAL tool, and the effectiveness of its learners.

These findings assisted in the development of measures of effective learning to produce effective CAL tools, hence, promote effective learning.

To aid the work in Chapter 3, a review of the history and background to the development of computer based media, classification of their type, and their application in construction was produced. This study assisted in developing a definition for Computer Assisted Learning 'CAL' tools and highlighted the of different types of educational media in helping the learning process. One important conclusion drawn, was that different types of computer based media, promote several types or levels of learning and no one media is capable of promoting all stages of the learning process.

Therefore, to help develop a strategy for implementing CAL tools effectively within the construction domain, several approaches were reviewed. None of these addressed the needs and demands of the construction domain. This conclusion led to the proposal of a framework for a strategic approach to the effective development and implementation of CAL tools, to promote learning in construction. Accordingly, a framework was developed defining the role of the educator, developer and user of CAL tools at various stages (the planning, implementation and evaluation stage). The different stages of the framework (planning, implementing and evaluating) address the factors addressed by Chapter 2, and their influence in promoting effective learning through the use of CAL.

The framework also considers the planning for CAL as the task of the educator, and requires the educational needs for CAL, its targeted users, motivational factors and the targeted learning strategies to be identified. It is proposed that effective planning leads to effective structuring of CAL tools. The second stage of the framework is the
implementation stage, which is considered the task of the educator and the developer. The implementation of CAL tools requires effective structuring (i.e. the content of CAL) and effective operations (i.e., the environment of CAL). To assist in monitoring effective implementation of CAL, formative (efficiency of CAL) and summative (effectiveness of CAL) evaluations are required, using various methods of testing and evaluating the effectiveness of CAL. This stage of the framework requires the involvement of the educator, developer and the users of CAL. This Chapter concluded the research hypothesis, in that:

- Qualitative measures of the effectiveness of CAL are insufficient.
- CAL can be effective if implemented strategically.

The work in Chapters 4 and 5 was initiated to verify the first hypothesis of the research.

Chapter 4 developed a study of simulation games and distinguished between the terms of games, role play, exercise and simulation games, providing a clear definition of computer based simulation games. The advantages and disadvantages of computer based simulation games were reviewed from literature, and their role in facilitating experiential learning were described, justifying their use and applications for engineering education, particularly construction. However, few case studies describing the effectiveness of simulation games exist. Even when such studies are carried out, qualitative rather than quantitative measures of the effectiveness of these tools are reported, depending on the educators’ observations and/or the participants’ comments.

Chapter 4 provided a defined description of the implementation and the structure of MERIT2, and adopted the approach introduced by the logical steps proposed by the framework developed in Chapter 3 to evaluate its effectiveness.

Measures of the success of MERIT2 are often demonstrated by the number of participants from academia or industry. This provided an ideal study to test the first hypothesis of the research, and produce quantitative rather than qualitative measures of its effectiveness. This investigation was guided by the evaluation criteria proposed by
the framework developed in Chapter 3, and suggested that MERIT2 is an effective CAL tool if:

- it achieved the aims and objectives it was originally created for;
- it proved motivating;
- it promoted the targeted learning strategies to facilitate ‘off the job’ learning.

To aid this investigation, a detailed study was undertaken in Chapter 5 to survey two samples of MERIT2 participants. Those who has participated;

- to promote their Continuous Professional Development, and
- to fulfil part of their academic requirements.

The first was a postal survey, enquiring about the participant’s opinion of the introductory stage and the operation of MERIT2, the value of MERIT2 as a learning medium and as a tool to promote learning in construction management, its relevance to their existing experience and their interest to take part again. The relationship between the participants’ opinion and their background were also investigated, applying relevant statistical methods. The results of this investigation showed that:

i. MERIT2 can be more effective in meeting the educational aim and objectives as a training tool for CPD if:
   a. the introductory stage of the game is improved and the quality of the preparatory material are improved;
   b. the quality of information in the manual is improved to suit participants’ to match participants’ background and previously gained experience;
   c. enough time is given to participants to make decisions after each round of the game, and
   d. there is enough feedback generated from the output reports, clarifying the consequences of the decisions made for filling in the bidding forms.

ii. MERIT2 proved motivating through
   a. participants’ response to their enjoyment of the simulation game,
   b. the value of the simulation game as a learning medium,
c. the participants expressed interest to take part again. Such interest was particularly expressed by first time participants; and
d. its relevance to the participants’ practical experience in the construction industry.

iii. MERIT2 met the participants’ educational needs in:
   a. demonstrating the nature of decisions made within a construction company,
   b. demonstrating the interlocking nature and complexity of construction management decision made within a construction company;
   c. enhancing their knowledge of decisions made on bids, labour allocation and project managers allocation, particularly for those with a civil engineering background;
   d. improved awareness of team work, communication and leadership skills, particularly by team leaders.

However, MERIT2 did not meet the participants’ needs in enhancing their knowledge of decisions made on overhead allocation and cash distribution and borrowings, resulting in poor knowledge gained in other areas of construction management promoted by MERIT2.

The results of the second survey shows that:

a. MERIT2 generally gained a better response to its value as an educational medium by students undertaking their postgraduate course in construction management, than those given to its value in promoting CPD by participants from industry.

b. MERIT2 is valued as a CAL tool to promote learning in construction management, however its effectiveness in reaching its targeted aims and objectives could be improved. These conclusions were reached as a result of a number of observations:

- Students undertaking their postgraduate courses showed more satisfaction with the introduction and briefing of MERIT2. This is credited to the environment of running MERIT2 and the direct lines of communications between the students and
the game controller. This can be considered a contributing factor to their higher responses to knowledge improved upon decisions on bids, project managers’ allocation and labour allocation.

- The quality of information given in the manual gained a low response by both population samples, similar behaviour was observed from responses given to knowledge improved upon decision made on overhead allocation and decisions on cash distribution and borrowings. Students’ responses from sample 2 to knowledge improved in other areas of construction management were generally higher than those given by the CPD participants in sample 1. However, responses given by both samples generally indicated less than fair knowledge improvement.

- Both population samples enjoyed and appreciated the value of MERIT2, although higher responses were given by the student population sample.

- The results of the pre-task and post task questionnaire surveys showed that taking part in MERIT2 improved the participants’ knowledge in principal areas of construction management targeted by the simulation game.

- The results of the confidence development survey, showed that MERIT2 improved the participants’ confidence in knowledge gained upon decisions on bids, labour allocation and project managers’ allocation after each round of the simulation game. However, less confidence was developed by participants after each round of the simulation game, on decisions made on overhead allocation and cash distribution and borrowing. Participants’ confidence on knowledge gained over the interlocking nature of decisions made was also reduced after each round.

- Little confidence was gained on the understanding of the information given in the manual.

- Participants’ confidence of team work increased after each round of the simulation game.

The main conclusions drawn from this study were:

- The introduction and briefing for the simulation game is not efficient, particularly when the exchange of information before and while taking part in MERIT2 is by post
• The quality of support material given to individuals taking part in MERIT2, must cater for the participants’ background, particularly their existing level of knowledge and experience of the areas introduced.

• Participants’ knowledge improvement, depends on their understanding of the interactive nature of the decisions made to fill in the decision forms. Failure to illustrate (either, by the simulation game controller, or by the feedback from the reports) the consequences of the decisions made, results in failure to reflect and reinforce the knowledge gained.

• Taking part in the simulation game once, gives an appreciation of the value of the simulation game. However, taking part once may not be sufficient to reflect the complicated nature of the simulation game.

The results of this study supports the first hypothesis of this research in that, qualitative measures are insufficient on their own as measures of the effectiveness of CAL.

To test the second hypothesis of the research, the study in Chapters 6 and 7 was initiated.

The study in Chapter 6 defined the term ‘Multimedia’, and provided an overview of the capabilities and limitations of using Computer Based Multimedia tools to aid learning in higher education. The application of Multimedia tools within higher education and the engineering discipline, also reviewed from literature. This study concluded that, despite the existing potential for the use of Multimedia CAL tools within higher education, there is a lack of its development and use within the construction domain. One potential area for application, is their use to aid the learning process of Quantity Surveying measurement rules from first principles, in relation to a standard code of practice, e.g. the SMM7.

One of the main stumbling blocks in teaching measurement is that students need to have an understanding of the construction technology process before they can begin to understand the measurement rules that govern the quantification process. This leaves the student facing a problem of not being able to understand the construction process.
due to their lack of construction technology knowledge, (i.e. of the elements that the
measurement rules are based upon). This also presents major problems with
undergraduate quantity surveying measurement module, as has been evidenced by
educators in the Department of Civil and Building Engineering at Loughborough
University.

The study described in Chapter 7 highlighted the problems faced in teaching QS
measurement modules in the traditional way, the difference in students’
backgrounds and their lack of ability to relate the abstract concepts to real life
construction processes. Also, the educators’ lack of resources to provide life
demonstrations of such processes, and how this results in repetitive explanations of
the subject area to different individuals. It described QSMM (Quantity Surveying
Measurement in Multimedia), an exercise developed to aid this problem, adopting
the strategic approach proposed in Chapter 3. For QSMM to be effectively and
efficiently developed, the role of the developer was not confined to the development
and implementation stage of QSMM, but also included the planning and evaluation
stage. For effective planning of QSMM, clear communications between the quantity
surveying educators (lecturers and tutors), the developer of QSMM and the
students were needed, by surveying individuals’ opinions to identify the existing
problems. Therefore a number of steps undertaken at the pre-implementation stage
showed that:

- the conventional method of teaching promoted a surface approach to learning,
  and the recognition of students’ needs is essential;
- although the QS tutors had defined their own educational needs and goals, and
  showed interest and motivation for implementing new technology, they were
  not fully aware of the students’ educational needs. There was a mismatch
  between what the educators thought the students’ difficulties were, and what
  the actual students’ difficulties were;
- Riding’s Learning Style Analysis showed that, although the Quantity Surveying
  students did not have a defined learning style during their first year in the
  undergraduate domain, their learning styles seemed to shape as they progressed
  through their course, with the imagery style dominating by their final year.
• Educators’ learning styles differed from the students’ learning styles (as expected due to their professional experience). QS tutors preferred students with learning styles that matched their own, and were aware of what style of learning they wanted the future graduate quantity surveyors to have.

To aid the effective development and implementation of QSMM, the followings steps were undertaken:
• Recognising the students’ background and their previous experience, assisted the structuring of QSMM in such a way, that suits students’ individual levels and backgrounds.
• Defining aims and objectives, learning styles and transferable skills initially assisted with effective structuring of information in presented by QSMM.
• Defining the relationship between time spent in learning and the integrated media assisted in planning for QSMM to be both time and cost effective.

Following the development of QSMM a number of post-task surveys were carried out, eliciting the following:
• the formative evaluation, showed that QSMM was run efficiently on the departmental server and was easily accessed by the students at all times. Also, QSMM was found user friendly with more than satisfactory levels of mapping and usability;
• the summative evaluation showed that QSMM was more effective that the conventional way of teaching. Its effectiveness was mainly concentrated on its functionality to assist students with their imagery learning difficulties. It enhanced students' learning skills and reduced the time taken to understand complex aspects. However, there was no evidence that QSMM was more effective for a particular style of learners;
• more than two thirds of the population found all aspects of QSMM an interesting way of presenting information and very helpful. Non of the students found QSMM confusing.

The main conclusions drawn from Chapter 7 are listed below.
• The framework developed in Chapter 3, was an effective guide for the strategic approach to planning, developing and evaluating QSMM.

• The direction of learning must target the required learning strategies associated with the future graduates, and focus on enhancing the related skills and abilities.

• A CAL tool can only be described as effective, if it meets the educational needs of educators and learners.

• Educators’ lack of unawareness of the difference in students’ learning styles, may be a contributing factor to students’ learning difficulties.

• Multimedia software tools, are effective for improving students’ imagery styles and simulating ‘off the job’ learning.

QSMM proved an effective and useful tool for teaching quantity surveying measurements from first principles. Its values is in its ability to divide elements of construction into its constituents and show how these fit together in animated sequences. This, in turn, improves students’ wholistic abilities of thinking, their imagery thinking style and also helps improve their analytic style of learning. By doing so, QSMM assists in overcoming the difficulties faced in a traditional lecture-led class room environment.

This study supports the second hypothesis of this research in that CAL is an effective educational tool within the construction domain, when tailored to learners specific needs and learning styles.

8.3 CONCLUSIONS OF THE RESEARCH

The following conclusions can be drawn from this research:

1. Experience is a key element to learning in construction, and CAL tools are useful resources for promoting experiential learning.

2. Measures of effective learning addressed by learning theory, provide a good guide for the implementation of effective educational tools, including CAL.
3. Defining a strategic framework for the implementation of CAL, was a useful guide to investigating the effectiveness of the MERIT2 simulation game, and to the planning, development and evaluation of QSMM courseware.

4. The evaluation of MERIT2 simulation game showed that quantitative analysis provides better measures of its effectiveness than qualitative analysis.

5. The evaluation of MERIT2 showed that its operation was inefficient and did not cater for the participants’ background. Also, its effectiveness does not only depend on its participants, but also on its structure.

6. Educators were unaware of their students’ difficulties in learning quantity surveying measurement rules.

7. QS educators’ preferred teaching students with learning styles that match their own.

8. QSMM proved effective, because it was tailored to meet the needs of its end users.

8.4 LIMITATIONS

Although the main aims and objectives of this research were met, this section highlights the limitations of this study as described below:

1. The samples surveyed to evaluate the effectiveness of MERIT2 simulation game, were not compatible in size. The first sample of 236 who worked in industry, was much larger than the second sample of 22 postgraduates. Although the compared results gave good comparisons to the population behaviour, more sample sizes would have provided more reliable results.

2. The nature of the first survey, required tracing back previous participants of MERIT2 who were working in industry at the time. This limited the study to post-task surveys, and dictated that the study only investigated the effectiveness of MERIT2 by comparing the results of pre-task and post-task surveys.

3. The scale of scores 1 (low) to 5 (high) used to surveys the participants’ opinion of different aspects of MERIT2 was broad. To reflect a more accurate opinion of the surveyed population, these scores should have been more clearly defined as: (1) very poor; (2) poor; (3) fair; (4) good and; (5) very good. A similar scale should have been applied (where applicable) to the other surveys.
4. The study undertaken to evaluate the MERIT2 simulation game did assess the participants' learning styles, to verify whether Civil Engineers carry the abilities of the convergent learning styles, as claimed in literature. The nature of the surveyed samples of MERIT2 participants, did not allow this study.

5. The study in Chapter 7, assessed the learning styles of undergraduate students in their first, second and third year. The time constraints in this research did not allow the study to assess the students’ learning styles as they progress to the third year. This would have given more reliable evidence that the learning styles of novice quantity surveyors is of imagery style.

6. The time constraints in this research, prevented the study of the students' long term performance in exams, as a result of introducing QSMM within the curricula.

8.5 FUTURE RESEARCH

The research findings and the various implications of the development of Computer Assisted Learning suggested directions for future investigations, such as:

The MERIT2 simulation game can improve its effectiveness by:

- Improving the introduction and briefing stage, and introducing more effective ways of communicating with participants, particularly for those who are based in industry. With the availability of new technology, a web-based learning environment would be ideal.
- The quality of information given in the manual should be improved.
- A demo version of the simulation game should be produced, to trial the simulation game before taking part, and develop an appreciation of interlocking nature of the decisions made.
- The structure of the simulation game should be improved by providing feedback to the consequences of decision made and clarifying the data output of the generated reports.

Following the development of this study, a new version of MERIT2 is under development, taking into consideration the above recommendations. It is further
recommended that strategic evaluation procedures are adopted during and after the development and implementation stage.

Since this research was initiated, work related to the ideas generated by this study have continued. For example, work concerning personal development learning strategies.

- Students' learning styles are assessed during their foundation year to study engineering at Loughborough University, as part of a study skill module. This aims at raising the students' awareness of their abilities and how they can improve their learning strategies.
- A project has been initiated to develop a process to promote a culture that will enable and support students and graduates to monitor, build and reflect upon their own personal development within the discipline of construction management.

Other areas of research funded by the Teaching and Learning Technology Programme (1998), is the development of strategic frameworks that will assist with the implementation of On Line teaching and learning material (The FOCUS project, ‘Framework for Optimising C&IT Uptake and Support’) and with the evaluation of Computer Assisted Learning tools (EASEIT-Eng ‘Evaluative and Advisory Support to Encourage Innovative Teaching - Engineering’).

It can also be claimed that, the potential use of CAL tools to assist with the visualisation process in Construction is being met, whether by using Multimedia tools, or Virtual Reality modelling. These tools may be produced as stand alone applications or in a shared on-line environment. Therefore, with the wide use of the new technology, educators are becoming more aware of the value of CAL tools to assist learning in construction.

However, there is very little research (if any) that has studied the long term effectiveness of CAL tools in construction and to whether these tools have any impact on:

- the students’ exam results;
- improving the quality of graduate engineers.
8.6 RECOMMENDATIONS

The results of the theoretical and empirical investigations obtained in this research led to the following recommendations for effective implementation of CAL tools in construction:

- Educators must become aware of the close links between learning theory and effective learning through the use of CAL tools. CAL tools hold the potential to shape individuals’ experiential skills required to meet the demands of the construction industry.

- To promote the experiential learning process in construction, educators must become aware of the different styles of CAL, and the stages of the learning process they promote.

- Educators must be aware of learning strategies required within different fields of construction, so that the relevant educational tools can be implemented to promote these strategies.

- Adopting strategic approaches to the development and implementation of CAL tools, will help promote effective tools. Existing frameworks for implementing CAL tools, do not necessarily mean that they can be adopted to suit educators’ specific needs for CAL. Educators must develop their own strategies for implementing CAL.

- Educators must recognise their students’ educational needs.

- Effective delivery of educational methods requires the educators’ awareness of their own teaching style and their students’ learning style.

- Qualitative measures for evaluating CAL tools are not sufficient on their own, these must be accompanied by quantitative measures.

This research project has developed a new framework for the effective development and deployment of CAL in the construction industry. Adoption of this framework and the above recommendations will significantly contribute to enhancing Computer-Aided Learning for both students and practitioners in the construction industry.
REFERENCES


Seeling, R. The Ba newRow I and II’ Department of Construction Methods and Management. Technischen Hochschule. Germany. "unpublished literature".


Http://www.port.ac.uk/adc/cal2.htm


APPENDIX A

Learning Styles
1. Kolb’s Learning Style Inventory

There are nine sets of four words listed below. Rank-order the words in each set by assigning a 4 to the word that best characterises your learning style, a 3 to the word that text characterises your learning style, a 2 to the next most characteristic word, and a 1 to the word that is least characteristic of you as a learner.

You may find it hard to choose the words that best characterise your learning style. Nevertheless, keep in mind that there are no right or wrong answers - all choices are equally acceptable. The aim is to describe how you learn, not to evaluate your learning ability.

Be sure to assign different rank number to each of the four words in each set: do not make ties.
<table>
<thead>
<tr>
<th>1. discriminating</th>
<th>tentative</th>
<th>involved</th>
<th>practical</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. receptive</td>
<td>relevant</td>
<td>analytical</td>
<td>impartial</td>
</tr>
<tr>
<td>3. feeling</td>
<td>watching</td>
<td>thinking</td>
<td>doing</td>
</tr>
<tr>
<td>4. accepting</td>
<td>risk-taker</td>
<td>evaluation</td>
<td>aware</td>
</tr>
<tr>
<td>5. intuitive</td>
<td>productive</td>
<td>logical</td>
<td>questioning</td>
</tr>
<tr>
<td>6. abstract</td>
<td>observing</td>
<td>concrete</td>
<td>active</td>
</tr>
<tr>
<td>7. present-oriented</td>
<td>reflecting</td>
<td>future-oriented</td>
<td>pragmatic</td>
</tr>
<tr>
<td>8. experience</td>
<td>observation</td>
<td>conceptualisation</td>
<td>experimentation</td>
</tr>
<tr>
<td>9. intense</td>
<td>reserved</td>
<td>rational</td>
<td>responsible</td>
</tr>
</tbody>
</table>
Scoring

The four columns of words above correspond to the four style scales: CE, RO, AC, and AE. To compute your scale scores, write your rank numbers in the boxes below only for the designated items. For example, in the third column (AC), you would fill in the rank numbers you have assigned to items 2, 3, 4, 5, 8, and 9. Compute your scale scores by adding the rank numbers of each set of boxes.

\[
\begin{array}{cccc}
2 & 3 & 4 & 5 \\
6 & 7 & 8 & 9 \\
\end{array}
\]

CE = \[\text{_____} \]

\[
\begin{array}{cccc}
1 & 3 & 6 & 7 \\
8 & 9 & & \\
\end{array}
\]

RO = \[\text{_____} \]

\[
\begin{array}{cccc}
2 & 3 & 4 & 5 \\
8 & 9 & & \\
\end{array}
\]

AC = \[\text{_____} \]

\[
\begin{array}{cccc}
1 & 3 & 6 & 7 \\
8 & 9 & & \\
\end{array}
\]

AS = \[\text{_____} \]

To compute the two combination scores, subtract CE from AC and subtract RO from AE. Preserve negative signs if they appear.

\[
\begin{array}{cccc}
AC - CE: & & \\
& & \Box - \Box = \\
AE - RO: & & \\
& & \Box - \Box = \\
\end{array}
\]

Plot these totals in the diagram below and connect them as a kite-profile.

The Learning Style Profile Norms for the learning Style Inventory (© David Kolb, 1976).

The following summary of the four basic learning style types is based on both research and clinical observations of these patterns of LSI scores.

The converger's dominant learning abilities are abstract conceptualisation (AC) and active experimentation (AE). This person's greatest strength lies in the practical application of such ideas. A person with this style seems to do best in those situations, such as conventional intelligence tests, where there is a single correct answer or solution to a question or problem. This person's knowledge is organised in such a way that
Kolb's learning style inventory

through hypothetical-deductive reasoning the person can focus it on specific problems. Research on this style of learning shows that convergers are relatively unemotional, preferring to deal things rather than people. That tend to have narrow technical interests and choose to specialise in the physical sciences. This learning style is characteristic of many engineers.

The diverger has the opposite learning strengths of the converger. This person is best at concrete experience (CE) and reflective observations (RO). This person's greatest strength lies in imaginative ability. This person excels in the ability to view concrete situations from many perspectives. We have labelled this style 'diverger' because a person with this style performs better in situations that call for the generation of ideas.
such as a ‘brainstorming’ idea session. Research shows that divergers are interested in people and tend to be imaginative and emotional. They have broad cultural interests and tend to specialise in the arts. Counsellors, organisation development specialists, and personnel managers tend to be characterised by this learning style.

The assimilator’s dominant learning abilities are abstract conceptualisation (AC) and reflective observation (RO). This person’s greatest strength lies in the ability to create theoretical models. This person excels in inductive reasoning and in assimilating disparate observations into an integrated explanation. This person, like the converger, is less interested in people and more concerned with the practical use of theories. For this person it is more important that the theory be logically sound and precise; in a situation where a theory or plan does not fit the ‘facts’, the assimilator would be likely to disregard or re-examine the facts. As a result, this learning style is more characteristic of the basic sciences and mathematics rather than the applied sciences. In organisations this learning style is found most often in the research and planning departments.

The accommodator has the opposite learning strengths of the assimilator. This person is best at concrete experience (CE) and active experimentation (AE). This person’s greatest strength lies in doing things - in carrying out plans and experiments - and oneself in new experiences. This person tends to be more of a risk taker than people with other three learning styles. We have labelled this person ‘accommodator’ because this person tend to excel in those situations where one must adapt oneself to specific immediate circumstances. In situations where a theory or plan does not fit the ‘fact’, this person will most likely discard the plan or theory. This person tend to solve problems in an intuitive trial and error manner, relying on heavily on other people for information rather than on one’s own analytic ability. The accommodator is at ease with people but sometimes seen as impatient and ‘pushy’. This person’s educational background is often in technical or practical fields such as business. In organisations people with this learning style are found in ‘action-oriented’ jobs, often in marketing or sales.
2. Honey and Mumford’s Learning Styles

This questionnaire is designed to find out your preferred learning style(s). Over the years you have probably developed ‘habits’ which help you benefit more from some experiences than from others. Since you are probably unaware of this, this questionnaire will help you pin-point learning preferences, so that you are in a better position to select learning experiences that suit your style.

There is no time limit to this questionnaire. It will probably take you 10-15 minutes. The accuracy of the results depends on how honest you can be. There are no right or wrong answers. If you agree more than you disagree with a statement, put a tick by it. If you disagree more than you agree, put a cross. Be sure to mark each item with either a tick or a stop.

1. I often take reasonable risks, if I feel it justified.
2. I tend to solve problems using a step-step approach, avoiding any fanciful ideas.
3. I have a reputation for having a no-nonsense direct style.
4. I often find that actions based on feelings are as sound as those based on careful thoughts and analysis.
5. The key factor in judging a proposed idea or solution is whether it works in practice or not.
6. When I hear about a new idea or approach I like to start working out how to apply it in practice as soon as possible.
7. I like to follow a self disciplined approach, establish clear routines and logical thinking patterns.
8. I take pride in doing a thorough, methodical job.
9. I get on best with logical, analytical people, and less well with ‘spontaneous’ ‘irrational’.
10. I take care over interpretation of data available to me, and avoid jumping to conclusions.
11. I like to reach a decision carefully after weighing up many alternatives.
12. I am attracted more to new unusual ideas than to practical ones.
13. I dislike situations that I cannot fit in a coherent pattern.
14. I like to relate my actions to a general principal.
15. In meetings I have a reputation of going straight to the point no matter what others feel.
16. I prefer to have as many sources of information as possible—the more data to consider the better.
17. Flippant people who don’t take things seriously enough irritate me.
18. I prefer to respond to events on a spontaneous, flexible basis rather than plan things out in advance.
19. I dislike very much having to present my conclusions under the time pressure of tight deadlines, when I could have spent more time thinking about the problem.
20. I usually judge other people’s ideas principally on their practical merits.
21. I often get irritated by people who want to rush headlong into things.
22. The present is much more important than thinking about the past or future.
23. I think that decisions based on a thorough analysis of all the information are sounder than those based on intuition.
24. In meetings I enjoy contributing ideas to the group, just as they occur to me.
25. On balance I tend to talk more than I should, and ought to develop my listening skills.
26. In meetings I get very impatient with people who lose sight of the objectives.
27. I enjoy communicating my ideas and opinions to others.
28. People in meetings should be realistic, keep to the point, and avoid indulging in fancy ideas and speculations.
29. I like to ponder many alternatives before making up my mind.
30. Considering the way my colleagues react in meetings, I reckon on the whole I am more objective and more unemotional.
31. At meetings I am more likely to keep in the background, than to take the lead and do most of the talking.
32. On balance I prefer to do the listening than the talking.
33. Most of the times I believe the end justifies the means.
34. Reaching the groups objectives and targets, should take precedence over individual feelings and objections.

35. I do whatever seems necessary to get the job done.

36. I quickly get bored with methodical detailed work.

37. I am keen on exploring the basic assumptions, principals and theories underpinning things and events.

38. I like meetings to run methodical lines, sticking to laid-down agendas.

39. I stay clear of subjective and ambiguous topics.

40. I enjoy the drama and excitement of a crises.
How to score

Put a tick in the appropriate boxes according to your answers to the questionnaire and total them. Double the number scored in each category.

Activists involve themselves fully and without bias in new experiences. They enjoy the here and now and are happy to be dominated by immediate experiences. They are open minded, not sceptical, and this tends make them enthusiastic about anything new. Their philosophy is: “I’ll try anything once”. They tend to act first and consider the consequences afterwards. Their are gregarious people constantly involving themselves with others but, in doing so, they seek to centre all activities around themselves.

Reflectors like to stand back to ponder experiences and observe them from many different perspectives. The thorough collection and analysis of data about experiences and events is what counts, so they tend to postpone reaching definitive conclusions for as long as possible. Their philosophy is to be cautious. They prefer to take back seat in meetings and discussions. They listen to others and get the drift of the discussion before making their own points. They tend to adopt a low profile and have a slightly distant, unruffled air about them. When they act it is part of a wide picture which includes the past as well as the present and others’ observations as well as their own.

Theorists adapt and integrate observations into complex but logical sound theories. They think problems through in a vertical, step by step logical way. They assimilate disparate facts into coherent theories. They tend to be perfectionists who won’t rest easy until things are tidy and fit into rational scheme. They like to analyse and synthesise. That are keen on basic assumptions, principals, theories, models and systems thinking. Their
philosophy prizes rationality and logic. Questions they frequently ask are: 'Does it make sense?' 'How does this fit with that?' 'What are the basic assumptions?'

Pragmatists are keen on trying out ideas, theories and techniques to see if they work in practice. They positively search out new ideas and take the first opportunity to experiment with applications. They are the sort of people who return from management courses brimming new ideas that they want to try up in practice. They like to get on with things and act quickly and confidently on ideas. They are impatient with ruminating discussion.
3. Riding’s Cognitive Style Analysis

What differences do styles make?
Consider the style characteristics of four trainers:

**John is an analytic-Verbaliser**
Socially he is out going and friendly but restrained and moderately formal. He is organised and can get on with things himself rather than needing help from others. He is consistent, but the negative side of this will be an inclination to rigidity and stubbornness.

He is structured in his approach to learning, and likes to set ideas out in a structured form, with clear headings and paragraphs. He has a good verbal memory, and is able to retain facts readily, particularly when presented in a verbal form.

In relationships with trainees he is moderately formal, and prefers to keep some distance between himself and them. His training tends to be structured, with him in control of the trainees’ learning. His primary mode of delivering his work rather than illustration although he may use tables.

**Christine is an analytic-imager**
Socially she is restrained and formal. At times she is socially unaware and often shows a rather stern exeria, which does not reflect how she really feels.

She organised and self reliant, and tends to get on with things rather than seeking help from others. Her approach to learning is structured. She learns best from diagrams and pictures rather than text. She is concise in writing and speech. In speaking, she can be hesitant, since words do not always come naturally, and she is not always fluent. Her relationship with trainees is formal, and she prefers to keep them at a distance. Her training is structured, and she controls trainees’ learning. Her training manner is typically interactive and she likes feedback. Her mode of delivery is typically in terms of illustration rather than words.
Graham is a Wholist - Verbaliser

Socially he is formal, extroverted and lively. He prefers to be people and enjoys group activity. He is warm and open, and is easy to get on with. He has a lot of go, although he can be changeable and may be unreliable. He can be too dependent on other for help.

He has a good verbal memory to retain facts readily, particularly when presented in verbal form. He does not find diagrams and illustrations helpful. Also he is less good spatially and does not have a strong sense of geographical direction. He is articulate and rarely lost for words, although this is sometimes a little overwhelming.

In relationships with trainees he is informal. His training does not tend to be highly structured, and he is happy for trainees to control their own learning. His training manner tend to be outgoing and lively. His primary mode of delivering tends to be words rather than illustrations.

Debbie is a Wholist - Imager

Socially she is informal and relaxed. She is fairly easy to get on with. She is usually diplomatic, socially aware and polite. Socially she tends to be reasonably outgoing. She is social, spontaneous, and warm in relationships although she is socially restrained and polite.

She benefits from having the learning material structured for her. She learns best from diagrams and pictures, rather than text. In speaking, she can sometimes be hesitant since words do not always come naturally and she is not always fluent.

In relationships with trainees she is moderately formal. Her training does not tend to be highly structured, and is generally happy for trainees to control their own learning. Her mode of delivery is when possible in terms of illustrations rather than words.
APPENDIX B

Categories of Computer Based Media
<table>
<thead>
<tr>
<th>Productivity</th>
<th>Communication tools</th>
<th>Learning tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Numerical processing</td>
<td>-electronic communication</td>
<td>-guide</td>
</tr>
<tr>
<td>- Programming</td>
<td></td>
<td>-aid</td>
</tr>
<tr>
<td>- Word processing</td>
<td>-conferencing</td>
<td>-discovery learning</td>
</tr>
<tr>
<td>- graphic design</td>
<td>-collaborative work</td>
<td>-micro-worlds</td>
</tr>
<tr>
<td>- control of equipment and instruments, data capture</td>
<td>-gateway to information and data banks</td>
<td>-games</td>
</tr>
<tr>
<td>- desk top publishing</td>
<td></td>
<td>-simulation</td>
</tr>
<tr>
<td>- presentation</td>
<td></td>
<td>-modelling</td>
</tr>
<tr>
<td>- integrated work environment</td>
<td></td>
<td>-visualisation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-assessment-formative and summative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-animation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-instructor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-tutorial</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-student modelling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-interactive multimedia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-problem solving</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-drill and practice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-revision resource</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-programmed learning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-intelligent tutoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-virtual reality</td>
</tr>
</tbody>
</table>

Table A The use of computers in education (Source, Doughty et al 1995)
<table>
<thead>
<tr>
<th>Type of computer based Media</th>
<th>Functionality</th>
</tr>
</thead>
</table>
| **Hypermedia**             | - **Hypertext**: The information items are 'documents', it may include text of varying length, pictures, diagrams, sound bites, etc. The links between these items are associative links constructed by the developer.  
- **Multimedia**: The combination of a system with audio visual media to give 'multimedia'. |
| **Interactice media**      | - **Simulation**: A computer based simulation is a program that embodies some model of an aspect of the world, allows the user to make inputs to the model, runs the model, and displays the results.  
- **Microworlds**: Similar to simulations, because they allow the user to act within a 'little world'. The added feature to microworlds is that they allow the user to express their description of some aspect of the world in a form understandable by, and therefore inspectable by, the program.  
- **Modelling**: A modelling program invites the learner to create their own model of a system, defined mathematically, which then runs, allowing the output to be compared with stored data of a real world system, or the program's own model. The user manipulates the model itself not just the parameters within a given model. |
| **Adaptive media**         | - **Tutorial programs**: A computer program that presents information, sets exercise for the students, accepts answers in some format, and gives feedback on those answers.  
- **Tutorial simulation**: These are a combination of two media, one is adaptive and one is interactive. The tutorial part provides extrinsic feedback to complement the intrinsic, in a form of a canned text on students' opinions.  
- **Tutorial systems**: Performs in the same tasks as a tutorial program but in a different way: generating the information from a database, generating exercise from rules using information already collected about the student, and generating feedback from both the database and the student record. |

Table B Types of educational media and their functionality (Source: Laurillard, 1993)
<table>
<thead>
<tr>
<th>Style of CAL</th>
<th>Its function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer-based drill and practice exercises</td>
<td>The computer must be capable of responding to student's outputs, which rules out natural language responses. Multiple-choice testing is often used. The range of subjects for which direct responses are possible include basic mathematics, simple aspects of language such as spelling and transliteration, many simulated practical skills. Mainly used for developing measurable skills.</td>
</tr>
<tr>
<td>Computer-aided instructions (CAI)</td>
<td>Comprising instruction and access to information, plus multiple choice questioning (i.e., Questions with right or wrong answers). For teaching mainly knowledge.</td>
</tr>
<tr>
<td>Computer-based training (CBT)</td>
<td>Comprising instruction, demonstration and testing (e.g., D&amp;P plus prior instruction and demonstration). For teaching skills.</td>
</tr>
<tr>
<td>Intelligent tutoring system (ITS)</td>
<td>Comprise CAI plus ability to respond constructively to students' multiple-choice selections. For example, when students make a particular mistake, they are provided with (hopefully) appropriate remedial instruction. However, the diagnosis of the causes of mistakes is fraught with difficulties, so it is easy to expect too much of ITS. On a good day, ITS can help remove misunderstandings and improve skills.</td>
</tr>
<tr>
<td>Resource based learning (RBL)</td>
<td>Computers and computer networks can give access to vast amount of information (e.g., Internet, including Search Engines and World Wide Web). Supports projects plus the learning of knowledge and know-how.</td>
</tr>
<tr>
<td>Simulation A</td>
<td>Simulation A; in which students can practice skills without the dangers and expense of failure typical of real situations (e.g., flight simulation).</td>
</tr>
<tr>
<td>Simulation B</td>
<td>Simulation B; in which the performance of designs or problem-solving can be tested by the use of simulation software. For teaching design skills, simulating the use of too many simulations can remove misunderstanding and improve skills.</td>
</tr>
<tr>
<td>Simulation C</td>
<td>In which the simulation software represents the properties and performance characteristics of some aspects of reality (e.g., economics, materials management) which can then be explored by observing the system's response to various inputs and thereby discovering or creating interconnections. Develops only knowledge unless accompanied by concept development activities.</td>
</tr>
<tr>
<td>Simulation D (Microworlds)</td>
<td>In which the consequence of the laws of science can be explored in simulated systems by observing the system's response to different inputs. In simulation, these laws can also be modified (e.g., an inverse square law can be modified to an inverse cube law) and the consequences explored. For developing understanding.</td>
</tr>
<tr>
<td>Multimedia (e.g., hypermedia)</td>
<td>Can combine Simulations B and C as well as CAI and RBL. It can therefore help with several kinds of learning in the cognitive domain. Can replace actual experiments with simulated ones. However, too much faith in simulated experiments can be misplaced. Perhaps simulations and simulated errors would be beneficial. Very expensive but usually motivating if done well.</td>
</tr>
<tr>
<td>Expert systems</td>
<td>Expert systems (e.g., in medicine and trouble-shooting in engineering). These encapsulate the know-how of experts, and can be explored or used by students as a guide for practice. For developing know-how (i.e., expertise) more rapidly than by actual practical experience.</td>
</tr>
</tbody>
</table>

Table C Styles of CAL (Source: EPC, 1996)
APPENDIX C

Media methods and Learning
<table>
<thead>
<tr>
<th></th>
<th>HyperText</th>
<th>Multimedia</th>
<th>Microworld</th>
<th>Modelling</th>
<th>Teaching program</th>
<th>Interactive simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. T can describe conception</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
</tr>
<tr>
<td>2. S can describe conception</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
</tr>
<tr>
<td>3. T can redescribe in light of S’s conception or action.</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
</tr>
<tr>
<td>4. S can redescribe in light of T’s redesription or S’s action</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
</tr>
<tr>
<td>5. T can adapt task goal in light of S’s description</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
</tr>
<tr>
<td>6. T can set task goal</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
</tr>
<tr>
<td>7. S can act to achieve task goal</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
</tr>
<tr>
<td>8. T can set up world to give intrinsic feedback on actions</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
</tr>
<tr>
<td>9. S can modify action in light of intrinsic feedback on action</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
</tr>
<tr>
<td>10. S can adapt actions in light of T’s description or S’s redesription</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
</tr>
<tr>
<td>11. S can reflect on interaction to modify description</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
</tr>
<tr>
<td>12. T can reflect on S’s action to modify redesription</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
<td>❏</td>
</tr>
</tbody>
</table>

Table A Media Methods and Learning (Source, Laurillard 1993)
APPENDIX D

MERIT2 Questionnaire Surveys
QUESTIONNAIRE 1
EVALUATION OF METIRT2

I. General details

a. Age

b. Current job

c. Please circle current qualifications

H.N.D B.Sc. M.Sc Ph.D others

d. Please indicate the main subject of your studies

e. Which year(s) did you play the MERIT2 simulation game?

f. Please indicate the nature and duration of your professional experience

<table>
<thead>
<tr>
<th>Field of experience</th>
<th>No. of years</th>
<th>No. of months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>--------------</td>
<td>---------------</td>
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<td></td>
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<td>---------------</td>
</tr>
<tr>
<td></td>
<td>--------------</td>
<td>---------------</td>
</tr>
</tbody>
</table>

II. Assessment of the game

Please rate the following aspects of the game giving a score from 1 (low) to 5 (high):

1. Overall enjoyment of the game

If you have scored less than 3, please answer yes or no to the followings questions:

Was your low score because of:

a. Difficulties in understanding the game?

b. Not enough time for making decisions?

c. Not satisfied with the game briefing and introduction?
d. Did not appreciate the relevance of the game?  

---

e. Other reasons, please specify  

---

2. Please give a score (1 to 5) to the following aspects:

a. Introduction and briefing to the game  

---

b. The quality of information given in the game  

---

c. Overall given information for filling in the bidding forms  

---

III. Valuation of the game

Please give a score (from 1 to 5) to the followings  

---

a. Value of the game as a learning medium  

---

b. Value of the game to demonstrate the inter-related nature of construction decisions  

c. Value of the game to encourage team work  

---

d. Value of the game to promote interest in areas outside your particular experience  

---

Please score '1' to '5' to the following aspects of the game for improving your knowledge in:

a. Decisions on bids  

---

b. Decisions on labour allocation  

---

c. Decisions on project manager allocation  

---

d. Decisions on overhead allocation  

---

e. Decisions on cash distribution borrowing  

---

Please give a score to any other area of knowledge that have been improved.
a. Organisational theory

b. Planning

c. Forecasting

d. Financial Management

e. Marketing

f. Group behaviour

g. Communication

h. Competitive bidding

IV. Relevance of the game

Please answer 'yes' or 'no' to the following:

a. Did taking part in MERIT2 at the time improve your professional ability?

If yes, please explain how briefly --------------------------------------------

b. Did you find any relevance between what you have learnt from the game and your practical experience?

If yes, please state how briefly --------------------------------------------

c. Which areas of decision making did you find was most simulating by the MERIT?

--------------------------------------------------------------------------

d. Can you think of other company management areas that can be simulated by MERIT2 or other similar games? Please specify

e. Would you be interested in playing the MERIT2 again?

Please state reasons --------------------------------------------------------------------------
QUESTIONNAIRE 2
MERIT 2: KNOWLEDGE TESTING QUESTIONNAIRE

1. Put the word ‘increase’ or ‘decrease’ in the appropriate place:

a. To ........ capital base, either ........ borrowing or ........ retained profit.

b. The ........ of turnover is dependent on ........ of capital base.

c. ........ in gearing ratio, causes ........ in borrowings.

d. Using the retained cash to ........ the capital base, will attract capital allowance and ........ tax corporation.

e. retained cash ........ debt burden and ........ company capital.

f. Additional borrowings ........ gearing ratio and ........ share prices.

g. ........ dividend paid to share holders, will make share prices ........

2. Please complete the following statements

a. Increased expenditure on overheads will improve the ........

b. Increased marketing efforts will increase ........

c. Increased tendering efforts, will increase the ........

d. Increased measurement efforts with respect to turnover, increases ........

3. Please tick the right answer:

(i) When making bidding decisions, what range of the % mark-up do you think your company should choose:

a. < 6%

b. 6% - 8%

c. 8% - 12%

d. 10% - 12%

e. > 12%
(ii) **On costs comprise:**

a. Direct costs plus planned costs
b. Site costs and labour costs for contract period.
c. Direct costs
d. Site costs plus project managers costs.

**Please re-arrange the followings in the order of importance**

The company decisions on whether to bid for jobs on offer depend on:

a. Type of job.
b. Distance from head office.
c. Company assets.
d. Size of job.
e. Number of jobs the company already have.
Please indicate by ticking the relevant box, how confidence do you feel about the followings aspects, after making your set of decisions

<table>
<thead>
<tr>
<th>Areas of knowledge</th>
<th>v. confident</th>
<th>confident</th>
<th>no confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding the information given in the manual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decisions on bids</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making decisions on labour allocation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making decisions on project managers allocation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making decisions on overhead allocation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making decisions on cash distribution and borrowings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>working as a team</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>understanding the interlocking nature of decisions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>understanding the output report</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>making the next set of decisions</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX E

SPSS analysis of output
1. Analysis of attributes

Participants’ background were grouped and analysed using the SPSS summary of frequencies. The SPSS data output enclosed describes the participants’ background in percentages.

Further analysis are carried out using the crosstabs chi-square test to determine the significance of the differences among k independent groups.

Hypothesis

The Null Hypothesis (H0): There is no significant difference between the groups (e.g., ages of participants and the level of education, or different ages groups and years of experience).

(H1): a greater proportion of the older age group hold higher level of qualification, or, have more years of experience.

Significance level.

$\alpha = 0.05$

Rejection region.

This region consists of all values of $x^2$ which are so large that the probability associated with their occurrence is equal or less than $\alpha$.

Decisions.

Two examples of the SPSS data output are enclosed in this part of Appendix E, and the decisions made are based on the followings:

Example 1: The probability of occurrence under H0 for $x^2 \geq 1.49958$ with $df = 1$ is (P=0.22074). The decision is to accept H0. This concludes that there is no significant difference between the proportions of different age groups and their level of education.
Example 2: The probability of occurrence of H0 for $x^2 \geq 50.00217$ with $df = 1$ is $P=0.00$. The decision is to reject H0 and accept H1. This concludes that greater proportions of the older participants have more years of experience than the younger age group. This illustrates the interaction or dependency of these groups.
<table>
<thead>
<tr>
<th>Value Label</th>
<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cum Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;25</td>
<td>165</td>
<td>44.5</td>
<td>44.5</td>
<td>44.5</td>
<td></td>
</tr>
<tr>
<td>&lt;25</td>
<td>131</td>
<td>55.5</td>
<td>55.5</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>236</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Valid cases 236  Missing cases 0

---

### Level of education

<table>
<thead>
<tr>
<th>Value Label</th>
<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cum Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSc and higher</td>
<td>25</td>
<td>10.6</td>
<td>10.6</td>
<td>10.6</td>
<td></td>
</tr>
<tr>
<td>Less than BSc</td>
<td>211</td>
<td>89.4</td>
<td>89.4</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>236</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Valid cases 236  Missing cases 0

---

### Subject of study

<table>
<thead>
<tr>
<th>Value Label</th>
<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cum Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil Eng</td>
<td>25</td>
<td>10.6</td>
<td>10.6</td>
<td>10.6</td>
<td></td>
</tr>
<tr>
<td>Non Civil Eng</td>
<td>211</td>
<td>89.4</td>
<td>89.4</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>236</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Valid cases 236  Missing cases 0
## Type of Experience

<table>
<thead>
<tr>
<th>Value Label</th>
<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cum Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No experience</td>
<td>5</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Consultants</td>
<td>63</td>
<td>26.7</td>
<td>26.7</td>
<td>28.8</td>
<td>100.0</td>
</tr>
<tr>
<td>Contractors</td>
<td>168</td>
<td>71.2</td>
<td>71.2</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>236</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Valid cases**: 236  
**Missing cases**: 0

## Years of Experience

<table>
<thead>
<tr>
<th>Value Label</th>
<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cum Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;3 years</td>
<td>138</td>
<td>58.5</td>
<td>58.5</td>
<td>58.5</td>
<td>58.5</td>
</tr>
<tr>
<td>≤3 or =3</td>
<td>98</td>
<td>41.5</td>
<td>41.5</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>236</td>
<td>100.0</td>
<td></td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

**Valid cases**: 236  
**Missing cases**: 0
2. Analysis of responses

Examples of the SPSS data output are enclosed this part of Appendix E, showing:

a. The summary of percentages of frequencies of scorings given to different aspects of the introductory stage of MERIT2. The data shows three groups of scorings of (< 3.3 and > 3), and the associated percentages of responses. The average scores are also shown. These analysis were obtained using the SPSS statistics summary of frequencies command.

b. One sample \( x^2 \) two tailed t-test. Examples of the data output generated from the SPSS analysis, using COMPARE MEANS / ONE SAMPLES T-TEST command. are enclosed for the introductory stage of MERIT2.

**Hypothesis.**

H0: The observed mean scores are 3 or close to 3.

H1: The observed mean is not 3 or close to 3.

**Results**

Testing the mean scores given by the sample population, against an expected mean score of 3, the results showed that a value of 3.0127 presenting the ‘observed’ mean score given by the population sample to the ‘introduction and briefing to MERIT2’. Also, that the mean difference between the expected and observed means scores is 0.01. Therefore, for 235 degrees of freedom, the critical value of \( t \) for a 5% level of significance (two tailed test) is 0.22. Hence we reject H0 at 5% level of significance. We can be 95’% certain that the mean scores of responses is close to 3.

c. Kruskall-Wallis one-way analysis of variance [H]. This is a useful test for deciding whether k independent samples are from different population. This test helps with the question to whether the differences among the samples signify genuine population differences or whether they represent merely chance variation such as are to be expected among several random samples from the same population. The Kruskal-Wallis technique tests the null hypothesis that the k samples come from the same
population or from identical populations with respect to averages. The test assumes that the variable under study has an underlying continuous distribution. It requires at least ordinal measurement of that variable.

**Hypothesis**

Null hypothesis. H0: there is difference among the scores given by different groups of participants.

**Rejection region.**

The region of rejection consists of all values of H (the statistics used in the Kruskal-Wallis) which are so large that the probability associated with their occurrence under H0 is equal to or less than \( \alpha = 0.05 \).

An example of the SPSS Kruskal-Wallis analysis for the introductory stage of MERIT2 is enclosed in this Appendix, investigating whether the difference in participants’ response to the quality of information given in the manual, differs amongst groups of participants because of their years of experience. The results show that the value of H=0.0393 is so small that the probability associated with it occurrence under H0 is (0.8426) > 0.05. We reject H0 (that the participants’ response is dependent on their years of experience).
Example 1:

Age by Level of education

<table>
<thead>
<tr>
<th>Age</th>
<th>Count</th>
<th>&gt;= BSc</th>
<th>&lt;BSc</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;25</td>
<td>14</td>
<td>91</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.1</td>
<td>93.1</td>
<td>44.5</td>
<td></td>
</tr>
<tr>
<td>&lt;= 25</td>
<td>11</td>
<td>120</td>
<td>131</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13.9</td>
<td>117.1</td>
<td>55.5</td>
<td></td>
</tr>
<tr>
<td>Column</td>
<td>25</td>
<td>211</td>
<td>236</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10.6</td>
<td>89.4</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Chi-Square Value DF Significance
----------------------------- ---------- ------- ------------
Pearson 1.49958 1 0.22074

Minimum Expected Frequency = 11.123

Example 2:

Age by Years of experience

<table>
<thead>
<tr>
<th>Age</th>
<th>Count</th>
<th>Exp Val</th>
<th>&lt;or=3</th>
<th>&gt;3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;25</td>
<td>88</td>
<td>61.4</td>
<td>17</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td></td>
<td>61.4</td>
<td>43.6</td>
<td>105</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td>&lt;= 25</td>
<td>50</td>
<td>6.6</td>
<td>81</td>
<td>131</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.6</td>
<td>54.4</td>
<td>131</td>
<td>131</td>
<td></td>
</tr>
<tr>
<td>Column</td>
<td>138</td>
<td>98</td>
<td>236</td>
<td>236</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>58.5%</td>
<td>41.5%</td>
<td>100.0%</td>
<td>100.0%</td>
<td></td>
</tr>
</tbody>
</table>

Chi-Square Value DF Significance
----------------------------- ---------- ------- ------------
Pearson 50.00217 1 0.00000

Minimum Expected Frequency = 43.602

Number of Missing Observations: 0
SPSS Cross tabs analysis and values of chi-square, to investigate the interaction between participants' ages and level of education.

Age by level of education

<table>
<thead>
<tr>
<th>Level of education</th>
<th>Count</th>
<th>Exp Val</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.00</td>
<td>14</td>
<td>91</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>11.1</td>
<td>93.9</td>
<td>44.5%</td>
</tr>
<tr>
<td>3.00</td>
<td>11</td>
<td>120</td>
<td>131</td>
</tr>
<tr>
<td></td>
<td>13.9</td>
<td>117.1</td>
<td>55.5%</td>
</tr>
<tr>
<td>Column</td>
<td>25</td>
<td>211</td>
<td>236</td>
</tr>
<tr>
<td>Total</td>
<td>10.6%</td>
<td>89.4%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Chi-Square

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>DF</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson</td>
<td>1.49958</td>
<td>1</td>
<td>.22074</td>
</tr>
<tr>
<td>Continuity Correction</td>
<td>1.02366</td>
<td>1</td>
<td>.31165</td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>1.48907</td>
<td>1</td>
<td>.22236</td>
</tr>
<tr>
<td>Mantel-Haenszel test for linear association</td>
<td>1.49322</td>
<td>1</td>
<td>.22172</td>
</tr>
</tbody>
</table>

Minimum Expected Frequency - 11.123

Number of Missing Observations: 0

SPSS Cross tabs analysis and values of chi-square, to investigate the interaction between participants' ages and years of experience.

Age by years of experience

<table>
<thead>
<tr>
<th>years of experience</th>
<th>Count</th>
<th>Exp Val</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Ages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.00</td>
<td>88</td>
<td>17</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>61.4</td>
<td>43.6</td>
<td>44.5%</td>
</tr>
<tr>
<td>3.00</td>
<td>50</td>
<td>81</td>
<td>131</td>
</tr>
<tr>
<td></td>
<td>76.6</td>
<td>54.4</td>
<td>55.5%</td>
</tr>
<tr>
<td>Column</td>
<td>138</td>
<td>98</td>
<td>236</td>
</tr>
<tr>
<td>Total</td>
<td>58.5%</td>
<td>41.5%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Chi-Square

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>DF</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson</td>
<td>50.00217</td>
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<td>.00000</td>
</tr>
<tr>
<td>Continuity Correction</td>
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<td>.00000</td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>53.16319</td>
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<td>.00000</td>
</tr>
<tr>
<td>Mantel-Haenszel test for linear association</td>
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<td>.00000</td>
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Minimum Expected Frequency - 43.602

Number of Missing Observations: 0
### Summary of frequencies of scorings to the 'the introductory stage of MEPIT2'

<table>
<thead>
<tr>
<th>Value Label</th>
<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid</th>
<th>Cum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;3</td>
<td>64</td>
<td>27.1</td>
<td>27.1</td>
<td>27.1</td>
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<td></td>
<td>3</td>
<td>100</td>
<td>42.4</td>
<td>42.4</td>
<td>69.5</td>
</tr>
<tr>
<td></td>
<td>&gt;3</td>
<td>72</td>
<td>30.5</td>
<td>30.5</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>236</td>
<td></td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Mean 3.01

Valid cases 236 Missing cases 0

### Summary of frequencies of scorings to the 'Quality of information given before starting MERIT2'

<table>
<thead>
<tr>
<th>Value Label</th>
<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid</th>
<th>Cum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;3</td>
<td>68</td>
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<td>28.8</td>
<td>28.8</td>
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<td></td>
<td>3</td>
<td>104</td>
<td>44.1</td>
<td>44.1</td>
<td>72.9</td>
</tr>
<tr>
<td></td>
<td>&gt;3</td>
<td>64</td>
<td>27.1</td>
<td>27.1</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>236</td>
<td></td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Mean 3.00

Valid cases 236 Missing cases 0

### Summary of frequencies of scorings to the 'Overall information given for filling in the bidding forms'

<table>
<thead>
<tr>
<th>Value Label</th>
<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid</th>
<th>Cum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;3</td>
<td>55</td>
<td>23.3</td>
<td>23.3</td>
<td>23.3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>102</td>
<td>43.2</td>
<td>43.2</td>
<td>66.5</td>
</tr>
<tr>
<td></td>
<td>&gt;3</td>
<td>79</td>
<td>33.5</td>
<td>33.5</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>236</td>
<td></td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Mean 3.10

Valid cases 236 Missing cases 0
SPSS output analysis / One Sample t-tests

a. Introduction and briefing to the MERIT2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number of Cases</th>
<th>Mean</th>
<th>SD</th>
<th>SE of Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q13</td>
<td>236</td>
<td>3.0127</td>
<td>.906</td>
<td>.059</td>
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</tbody>
</table>

Test Value = 3

<table>
<thead>
<tr>
<th>Mean Difference</th>
<th>95% CI</th>
<th>t-value</th>
<th>df</th>
<th>2-Tail Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>.01</td>
<td>-.103</td>
<td>.129</td>
<td>.22</td>
<td>235</td>
</tr>
</tbody>
</table>

B. Quality of information given before starting MERIT2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number of Cases</th>
<th>Mean</th>
<th>SD</th>
<th>SE of Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q14</td>
<td>236</td>
<td>2.9661</td>
<td>.870</td>
<td>.057</td>
</tr>
</tbody>
</table>

Test Value = 3

<table>
<thead>
<tr>
<th>Mean Difference</th>
<th>95% CI</th>
<th>t-value</th>
<th>df</th>
<th>2-Tail Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>-.03</td>
<td>-.145</td>
<td>.078</td>
<td>-.60</td>
<td>235</td>
</tr>
</tbody>
</table>

C. Overall information given for filling in the bidding forms

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number of Cases</th>
<th>Mean</th>
<th>SD</th>
<th>SE of Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q15</td>
<td>236</td>
<td>3.1017</td>
<td>.879</td>
<td>.057</td>
</tr>
</tbody>
</table>

Test Value = 3

<table>
<thead>
<tr>
<th>Mean Difference</th>
<th>95% CI</th>
<th>t-value</th>
<th>df</th>
<th>2-Tail Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>.10</td>
<td>-.011</td>
<td>.214</td>
<td>1.78</td>
<td>235</td>
</tr>
</tbody>
</table>
SPSS data output showing the result of Chi-Square Tests, to investigate whether participants' scores are given at random

### Introduction and briefing to the game

<table>
<thead>
<tr>
<th>Cases</th>
<th>Category</th>
<th>Observed</th>
<th>Expected</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;3</td>
<td>64</td>
<td>78.67</td>
<td>-14.67</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>100</td>
<td>78.67</td>
<td>21.33</td>
</tr>
<tr>
<td></td>
<td>&gt;3</td>
<td>72</td>
<td>78.67</td>
<td>-6.67</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>236</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chi-Square 9.0847  D.F. 2  Significance .0106

--- Chi-Square Test

### Quality of information given in the manual

<table>
<thead>
<tr>
<th>Cases</th>
<th>Category</th>
<th>Observed</th>
<th>Expected</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;3</td>
<td>68</td>
<td>78.67</td>
<td>-10.67</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>104</td>
<td>78.67</td>
<td>25.33</td>
</tr>
<tr>
<td></td>
<td>&gt;3</td>
<td>64</td>
<td>78.67</td>
<td>-14.67</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>236</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chi-Square 12.3390  D.F. 2  Significance .0021

--- Chi-Square Test

### Overall information given for filling in the bidding forms

<table>
<thead>
<tr>
<th>Cases</th>
<th>Category</th>
<th>Observed</th>
<th>Expected</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;3</td>
<td>55</td>
<td>78.67</td>
<td>-23.67</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>102</td>
<td>78.67</td>
<td>23.33</td>
</tr>
<tr>
<td></td>
<td>&gt;3</td>
<td>79</td>
<td>78.67</td>
<td>.33</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>236</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chi-Square 14.0424  D.F. 2  Significance .0009
### Kruskal-Wallis 1-Way Anova / SPSS analysis of output

#### Introduction and briefing to MERIT2
by Years of experience

<table>
<thead>
<tr>
<th>Mean Rank</th>
<th>Cases</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>119.20</td>
<td>138</td>
<td>Years of experience (\leq 25)</td>
</tr>
<tr>
<td>117.52</td>
<td>98</td>
<td>Years of experience (&gt; 25)</td>
</tr>
</tbody>
</table>

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236 Total

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<tr>
<th>Chi-Square</th>
<th>D.F.</th>
<th>Significance</th>
<th>Chi-Square</th>
<th>D.F.</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
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<td>.0345</td>
<td>1</td>
<td>.8526</td>
<td>.0394</td>
<td>1</td>
<td>.8426</td>
</tr>
</tbody>
</table>

Corrected for ties
3. Interdependency of responses

The Pearson's Correlation Coefficient R is used as a measure of the linear association between two variables. This part of Appendix E shows the results of the SPSS data output and a generated value of Pearson's R = 0.18340 for the linear association between the participants' response to the introduction and briefing to MERIT2 and the their response to their knowledge improved on decisions made on bids. This value of R reflects a positive association, however it is not strongly linear. This can also be observed from the distribution in the table of frequencies presented.
Pearson's correlation coefficient

Introduction and briefing to MERIT2 by Decisions on bids

<table>
<thead>
<tr>
<th>Decisions on bids</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>14</td>
<td>25</td>
<td>7</td>
<td>1</td>
<td>51</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>16</td>
<td>37</td>
<td>24</td>
<td></td>
<td>78</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>16</td>
<td>27</td>
<td>27</td>
<td>4</td>
<td>77</td>
</tr>
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<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>Column</td>
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<td>52</td>
<td>100</td>
<td>65</td>
<td>7</td>
<td>236</td>
</tr>
<tr>
<td>Total</td>
<td>5.1</td>
<td>22.0</td>
<td>42.4</td>
<td>27.5</td>
<td>3.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Statistic: Pearson's R

Value: .18340
APPENDIX F

Measurement tutorials
NOTES:

1. 150mm. veg. soil to be preserved 50m. from excavation on site in spoil heaps.

2. hardcore blindered with 50mm. sand

3. 1000g. polythene d.p.m. under slab, tied into a.p.c. and with 100mm. laps at sides and ends.

4. Bitumen felt a.p.c. to B.S.1243 Type 1F with 100mm. laps.

5. Galvanised wire wall ties to B.S.1243 3no. per m²

6. Concrete - foundations 21 N/mm² -
   slab     28 N/mm² -

7. Existing ground level over whole of site = 100.50
All external brickwork finished in facings and flush pointed.  

Hollow wall External skin half brick wall in facings in cement mortar (1:3)  
50mm cavity with galvanized butterfly wall ties (4 per m²)  
Inner skin half brick wall in common bricks in cement mortar (1:3)  

All internal brickwork finished fair face and flush pointed  
Internal partition walls in common bricks in cement mortar (1:3)  

Loughborough University of Technology  
Department of Civil and Building Engineering  
Commercial Management & Quantity Surveying Practice and Procedure Drwg X/8/94
APPENDIX G

QSMM questionnaire surveys
QUESTIONNAIRE 1

USABILITY OF QSMM

Please put a circle around the appropriate score:

1. How easy was it for you to interact with the courseware
difficult easy
1  2  3  4  5

2. How easily could you navigate through the content of the courseware?
difficult easy
1  2  3  4  5

3. How well did you manage to recognise the available options and could choose the one you wanted.
difficult easy
1  2  3  4  5

4. How powerful were the diagrams in presenting the required information
not powerful very powerful
1  2  3  4  5

5. How comfortable did you feel with the colours presented on the screen.
not comfortable very comfortable
1  2  3  4  5

6. How would you classify the clarity of information given in the package
not clear very clear
1  2  3  4  5
7. **How well do you think the media used (animation and photographs) combine to produce an effective whole.**

<table>
<thead>
<tr>
<th>did not combine</th>
<th>combined very well</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

8. **How would you assess the overall functionality of the courseware in meeting the learning objectives.**

<table>
<thead>
<tr>
<th>not functional</th>
<th>highly functional</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

9. **What was it about the package that you did not like?**

________________________________________________________________________

________________________________________________________________________

10. **What was it about the package that you most liked?**

________________________________________________________________________

________________________________________________________________________

Would you consider using this method of teaching rather than the traditional way of teaching. Please state why?

________________________________________________________________________

________________________________________________________________________

Other comments
This is a pre-task questionnaire, designed to investigate the educators awareness of their students difficulties when solving the QS measurement tutorials in a traditional way. The same questionnaire was rephrased to investigate the students difficulties faced in understanding these tutorials.

Please study the exercise attached, and answer the appropriate sections

1. Which areas of the exercise do expect the students difficulties lie within most?
   - Reading and understanding the drawings given in the question
   - understanding what is required of the question
   - Calculating the depth of reduced excavation
   - Calculating the centre line of the trench
   - Imagining how the backfilling of soil and compacting process takes place
   - Measurement of earth work support
   - Measurement of the projection of the walls and the cavity in walls.
   - Imagining what wall ties are like and the type of engineering bricks used
   - Imagining how the quantities of soil are added, deducted and disposed off or on site.
   - Calculating the internal and external girths
   - Imagining the damp proof coarse
   - measurement of quantities for the hard core, concrete slab and screed
   - Referring to the SMM7, and understanding the items refereed to in the code.

Other difficulties, please specify:


Q. What tools would you use in explaining these difficulties?

a. Chalk and Blackboard
b. Overhead projector
c. Photographs from site
d. A video that shows different stages of the construction
e. A computer package, if yes, please give details

f. Others, please specify

Q. Is there any CAL packages in teaching Quantity Surveying from first principals that you are aware of and are used elsewhere?

If yes, please give details

If yes, please specify why you would like or would not like to use any of these packages.

Q. Are you happy about your method of teaching, or would wish to have other methods

Please specify
QUESTIONNAIRE 3
POST-TASK QUESTIONNAIRE / ASSESSMENT OF QSMM

Please work your way through the package carefully and answer the following questions

1. How useful did you find our further explanation of the question by using animation
   a. very useful, as it solves one of the major issues
   b. states the obvious
   c. is an interesting way of presenting information
   d. confusing, please state why and give an alternative

2. How helpful do you feel the package is, in helping the students with their understanding the depth of reduced excavation
   a. very useful, as it solves one of the major issues
   b. states the obvious
   c. an interesting way of presenting information
   d. confusing, please state why and give an alternative

3. Calculating the centre line of trench
   a. very useful, as it solves one of the major issues
   b. states the obvious
   c. an interesting way of presenting information
   d. confusing, please state why and give an alternative
4. Demonstrating the backfilling and compacting of materials
   a. very useful, as it solves one of the major issues
   b. states the obvious
   c. an interesting way of presenting information
   d. confusing, please state why and give an alternative

5. How would you classify the demonstration of E.W.S.
   a. very useful, as it solves one of the major issues
   b. states the obvious
   c. an interesting way of presenting information
   d. confusing, please state why and give an alternative

6. Demonstrating the foundation walls, the projection of walls, the cavity in walls, the wall ties and type bricks used.
   a. very useful, as it solves one of the major issues
   b. states the obvious
   c. an interesting way of presenting information
   d. confusing, please state why and give an alternative

7. Demonstrating the quantities of soil deducted, added and disposed off site or on site.
   a. very useful, as it solves one of the major issues
   b. states the obvious
   c. an interesting way of presenting information
d. confusing, please state why and give an alternative

8. Diagrams presenting the calculations of internal girths and external girths

a. very useful, as it solves one of the major issues
b. states the obvious
c. an interesting way of presenting information
d. confusing, please state why and give an alternative

9. Demonstration of the Damp proof coarse

10. Demonstration of the different steps of construction that is taken place to fill the foundation.

a. very useful, as it solves one of the major issues
b. states the obvious
c. an interesting way of presenting information
d. confusing, please state why and give an alternative

11. Demonstration of the different parts of the code by referring to each item.

a. very useful, as it solves one of the major issues
b. states the obvious
c. an interesting way of presenting information
d. confusing, please state why and give an alternative

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APPENDIX H

Screen shots of QSMM
Setting down dimensions

TRADITIONAL DIMENSION PAPER

The dimensions are measured from the drawings by the taker-off, who uses paper ruled thus:

| 1 | 2 | 3 | 4 |

These columns are not usually numbered, click on each number to identify these columns.

This is a dimension column, in which the measurements are set down as taken from the drawings.

An example demonstrating the lecture notes produced in QSMM

A front page to access the tutorial questions
Specifications

1. 150 mm vegetable soil to be preserved 50 m from excavation on site in spoil heaps.

2. Hardcore blinderd with 50 mm sand.

3. 1000 g polythene d.p.c. under slab, tied into d.p.c. and with 100 mm laps all sides and ends.

4. Bitumen felt d.p.c. to B.S. 743 type with 100 mm laps.

5. Galvanized wire wall ties to B.S. 1243, 30 m²

6. Concrete - foundations 11 N/mm² - 20 aggregates

7. Existing ground level over whole of site - 100.50

Tutorial 1

Specifications

All external brickwork finished in facing and flash pointed.
Hollow wall. External skins half brick wall in facing in cement mortar [1:3]

50 mm cavity with galvanized butterfly ties [4 per m²]

Tutorial 2

319
<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Topped for preservation</td>
</tr>
<tr>
<td>2</td>
<td>To reduce levels</td>
</tr>
<tr>
<td>3</td>
<td>Basements and the like</td>
</tr>
<tr>
<td>4</td>
<td>Tops (m)</td>
</tr>
<tr>
<td>5</td>
<td>Trenches, width ≤ 0.30 m</td>
</tr>
<tr>
<td>6</td>
<td>Trenches, width &gt; 0.30 m</td>
</tr>
<tr>
<td>7</td>
<td>For pile caps and ground beams between piles</td>
</tr>
<tr>
<td>8</td>
<td>To bench sloping ground to receive filling</td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Average depth stated (m)</td>
</tr>
<tr>
<td>11</td>
<td>Maximum depth &lt; 0.25 m</td>
</tr>
<tr>
<td>12</td>
<td>Maximum depth &lt; 1.00 m</td>
</tr>
<tr>
<td>13</td>
<td>Maximum depth &lt; 2.00 m</td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

**A break down of the measurement items (red text presents the hot links)**

**D20.2.1.1**

D20 Excavation and filling

<table>
<thead>
<tr>
<th>Excavating</th>
<th>1 Topped for preservation</th>
<th>1 Average depth stated (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>To reduce levels</td>
<td>1 Maximum depth &lt; 0.25 m</td>
</tr>
<tr>
<td>3</td>
<td>Basements and the like</td>
<td>2 Maximum depth &lt; 1.00 m</td>
</tr>
<tr>
<td>4</td>
<td>Tops (m)</td>
<td>3 Maximum depth &lt; 2.00 m</td>
</tr>
<tr>
<td>5</td>
<td>Trenches, width ≤ 0.30 m</td>
<td>4 and thereafter in 2.00 m</td>
</tr>
<tr>
<td>6</td>
<td>Trenches, width &gt; 0.30 m</td>
<td>stages</td>
</tr>
<tr>
<td>7</td>
<td>For pile caps and ground beams between piles</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>To bench sloping ground to receive filling</td>
<td></td>
</tr>
</tbody>
</table>
A cross section through the ground, demonstrating to the students the quantity that are required to be measured in tutorial 1.

An example of using animations to demonstrate the process of backfilling and compacting the soil.
Guiding the students through the solution in tutorial 1