IN-SERVICE TRAINING FOR COMPUTER-AIDED DESIGN IN BUILDING SURVEYING

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CONTAINS

PULLOUTS

Abstract

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In-Service Training for Computer-Aided Design in Building Surveying

The investigation was undertaken firstly to identify, classify and assess requirements and methods for in-service training in the use of computer-aided design (CAD) systems in UK building surveying practice. The second purpose was to develop, test and assess alternative instructional methods for practitioners to acquire and develop capabilities for appropriate use of CAD.

Requirements, opportunities and constraints were informed through discussion with practitioners, suppliers of CAD systems or associated services, and a postal survey of 50 UK building surveying practices. Collated information was considered within Romiszowski's (1984) framework for problem solving in the organisation. Conventional methods for CAD training in the UK construction industry, and relevant instructional theory, were investigated in a literature search. Alternative instructional models and methods were identified and developed through an action research methodology based upon Cohen and Manion (1989). Proposals were assessed conceptually using the first three of Popper's (1959) four tests for theories. Prototyping core components, substantially by computer-based methods, and classroom experiments with students of building surveying, or clients of the Leicester CAD Centre, both at De Montfort University, were used in place of Popper's fourth test.

The research findings contribute detailed analysis of requirements, provision and constraints to a sparse knowledge base for use of CAD in building surveying. They also provide a critical review of conventional methods for developing users of the technology in this domain. Three core principles are proposed to guide the policies and actions of building surveying practices in relation to CAD, emphasising integration of staff development within an overall CAD strategy. An alternative instructional model, synthesised from results across the research programme, is recommended for developing relevant practical capabilities with CAD. Corresponding specifications are made for a hybrid of manual, interpersonal and computer-based methods for its implementation. The model is set in the context of wider considerations for effective use of CAD technology, and is independent of particular software systems, types of workplace and trainee. Theoretically the model is capable of rapidly enabling staff in any practice to apply relevant CAD hardware and software effectively to authentic tasks, and subsequently contribute to developing application methods in the workplace. In conjunction with recommended operational principles the alternative instructional model improves significantly upon conventional methods identified for in-service training in CAD by provision for strategic integration, system independence, and responsiveness to local requirements.

The investigation concluded by identifying four foci for further research and development to overcome constraints on implementing the model by the methods prototyped. A fifth focus recommends investigation of an optimal model and methods to develop capabilities of staff in building surveying practices for appraising, implementing, managing and developing the use of CAD systems.

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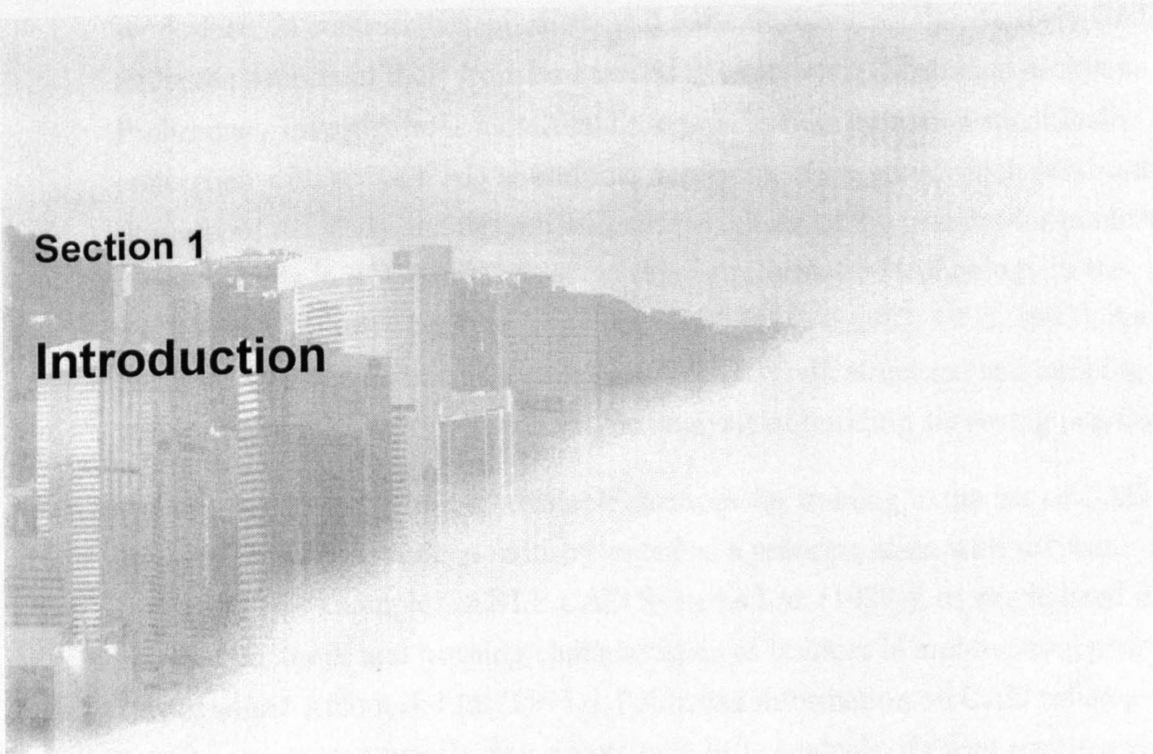
Section 1

Introduction



1.1 Origins and context for the investigation

The varied requirements for data capture and processing in building surveying practice provide prima facie opportunities for effective use of the range of CAD and related application systems available to the UK construction industry[1]. Of the issues affecting successful use of CAD software in building surveying, training for the development of practical capabilities was the most accessible for investigation by the author as a full-time lecturer in built environment applications of information and communication technology (ICT).

The current research programme originated in the early 1990s from a discrepancy regularly encountered by staff in the Leicester CAD Centre (2001) at Leicester Polytechnic, now De Montfort University. In the first instance manufacturers and suppliers of CAD systems usually commended their products to users by the ease with which they could be learned and applied in the workplace. In contrast, organisations and individuals attempting to apply CAD to authentic aspects of their workload tended to experience substantial problems. Preliminary investigations identified little published information specifically concerned with use of CAD in building surveying, a situation which persisted throughout the study and despite widespread uptake of the Internet for publishing developments in ICT. Three major surveys of information technology in the construction industry between 1987 and 1993, (CICA, 1987, 1990, 1993), for example, targeted architects, quantity surveyors, civil, structural and building services engineers, but omitted specific analysis of building surveying practice.

Preliminary investigation of available methods for training in the use of CAD systems in the construction industry revealed a preoccupation with software functions, (for example GABLE CAD Systems Ltd. (1987)), or emphasised the working methods and learning characteristics of trainees in architectural practice, (for example Autodesk Ltd. (1991)). Published information on CAD training was found to be predominantly descriptive with little analysis of client requirements or alternative instructional methods. In consequence, when the research programme started in July 1991, the author was assembling information on good CAD practice in an ad hoc way from a small number of published sources and

1 The range of proprietary systems available at the start of the research programme was summarised in New Builder (1993). The number has since been substantially reduced by a trend for wider use of Autodesk products.

contact with practitioners. Design of instructional material for use in CAD components of undergraduate building surveying programme at De Montfort University was based more upon a general systems methodology than specific theoretical underpinning, as evident in Watts (1990). Results achieved from using these resources could fall short of a trainee's expectations, encouraged by the claims of software suppliers, to rapidly assimilate relevant knowledge and practical capabilities. Conspicuous deficiencies of the knowledge base and instructional methods at the time concerned assessment of a client organisation's training requirements, and matching prior knowledge of trainees with appropriate instructional strategies. These factors in combination were perceived to require a more rigorous investigation of in-service training for the use of CAD systems in building surveying practice. The educational context for such an investigation was summarised effectively by Reigeluth (1983, p.xi) when prefacing a volume dedicated to increasing knowledge about how to improve instruction. The work of its 14 contributors was, he maintained, founded on the premise that the process of learning could be made easier and more enjoyable:

> "During the past twenty-five years, a young discipline has developed to so improve instruction. This discipline about *Instruction* has produced a growing knowledge base about methods of instruction and their effects for different kinds of goals, content, and learners. Because it is a very new discipline, the knowledge that has been generated so far has tended to be piecemeal, and instructional researchers have tended to develop independent "knowledge bases". Moreover, different researchers often use different terms to refer to the same phenomenon, and they often use the same term to refer to different phenomena. The result has been somewhat chaotic."

1.2 Scope and aims of research

The research programme was concerned with identifying cost-effective methods by which personnel in building surveying practice could acquire, maintain and develop appropriate capabilities for using CAD and related software systems in the workplace. For this purpose building surveying practice was understood to include the activities described in Appendix 1. A central premise of the study was that optimising training for use of CAD in this domain depended upon thorough and accurate assessments of requirements and best working practices. As a result the first objective of the study was to identify, classify and assess in-service training requirements and methods for the use of computer aided design and related systems in building surveying. At 1993 more than 10% of Chartered Building Surveyors were practicing outside of the United Kingdom.

(RICS, 1993) and it was beyond the scope of this study to investigate their working methods or training requirements. Since building surveyors collaborate and compete with other built environment professionals, the research necessarily considered relevant aspects of CAD and related software systems within the wider UK construction industry, primarily for architectural practice.

No critical and detailed assessment was available of requirements and existing methods for CAD training in the UK construction industry when the research programme began. The investigation was expected, therefore, to reduce this apparent gap in the knowledge of practitioners deploying CAD systems in the building surveying component of the industry, and their providers of training and related services. In this context the second objective of research was to develop, test and assess alternative instructional methods for acquiring and developing CAD skills. The term "alternative instructional methods" refers to techniques other than those generally in concurrent use by the industry for acquiring and developing CAD skills. The assumption underlying this objective was that optimising training for use of CAD depended upon explicit implementation of an appropriate instructional model. Reigeluth (1983, p.xii) again provides context for a major task in the research programme:

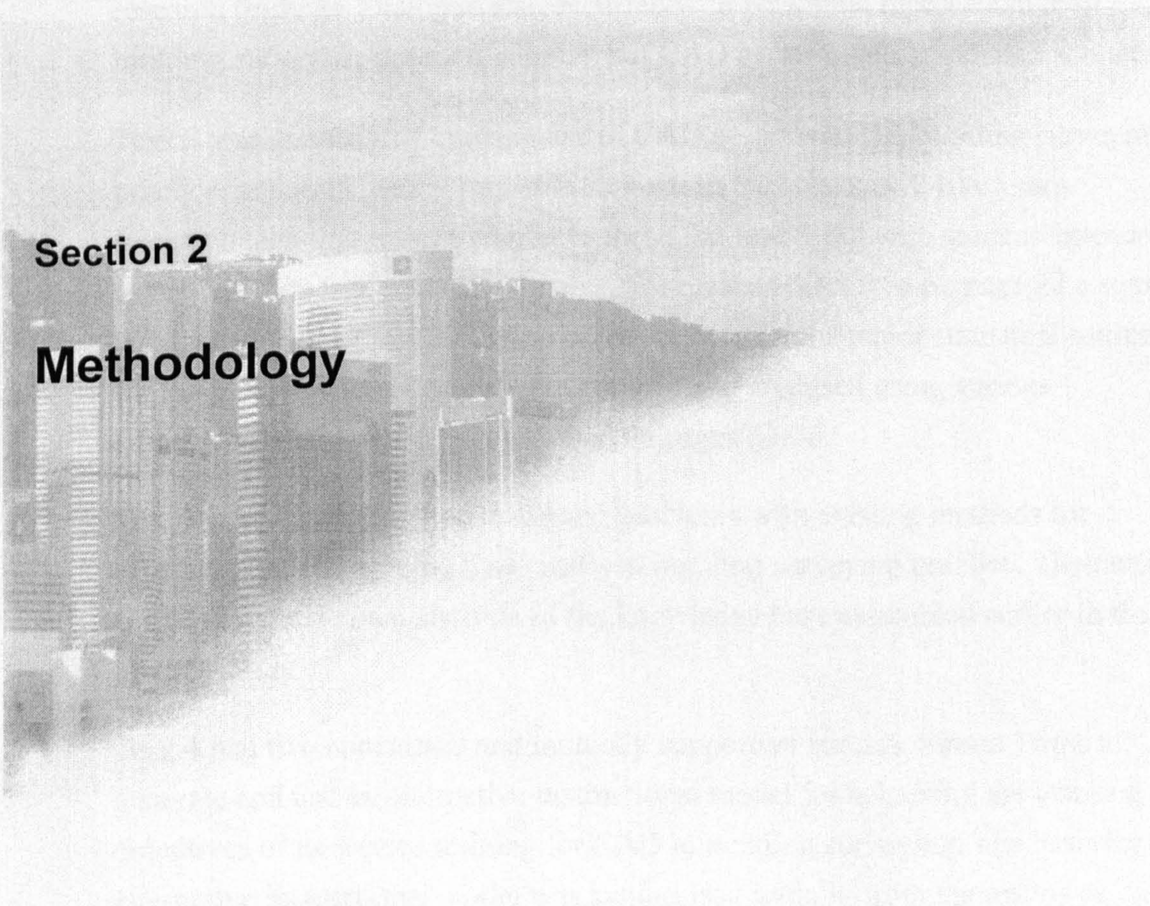
> "One can envision a time when there will be a variety of different models of instruction, each prescribing the best available methods for achieving a different kind of learning goal under different kinds of conditions. One can also envision researchers all over the world building upon this common knowledge base, continually improving and refining those models."

The primary route to an appropriate model was expected to require analysis synthesising in-service training requirements with relevant prescriptions and methods from instructional theory and practice. Comparative analysis of available theories for instruction and learning, and examination of their incidence in training for the use of CAD systems, was consequently a significant part of the investigation.

The scope and aims discussed above were more wide ranging than commonly found in Ph.D. research programmes. Due consideration of implications from this characteristic concluded that a detailed investigation within narrower parameters could not adequately address recurrent deficiencies of existing practices for training in CAD.

Section 2

Methodology



2. Methodology

2.1. Overview of methods

The methodology for the research programme involved five main tasks and a corresponding range of activities, as summarised in pages 21-23 and Fig. 1, below.

Task 1 was to identify and classify relevant theories, practices, research and development directly, or indirectly, relevant to training for CAD in building surveying, and selected construction-related practices. The main purpose for this part of the investigation was to clarify the range of current and potential training methods, inform assessment of existing approaches and generation of alternatives in Tasks 3 and 4. Primary activities were a literature search with subsequent analysis of key texts, journal and periodical articles, and published research findings. Dialogue also occurred with personnel representative of building surveying practice, suppliers of CAD systems and associated services.

Task 2 was quantifying existing use of CAD systems in UK building surveying practice, and anticipating probable changes in the subsequent five years. Research techniques were similar to those for Task 1 but with sources extended to include data from existing surveys. For reasons discussed on page 28 a sample survey of UK building surveying practices became the major statistical source for the investigation. Results were collated and analysed using various computer-based techniques described on pages 33-36.

Task 3 was identifying and analysing problems with existing methods for acquiring and developing CAD skills in building surveying practice. The main activity was sustained analysis of the knowledge base assembled earlier in the investigation.

Task 4 had two concurrent and mutually supportive strands. Strand 1 was to generate and test an alternative instructional model for achieving the learning objectives of in-service training for CAD in building surveying. The basis for an alternative instructional model was synthesised initially from the results of Tasks 1-3 using the computer-based techniques described on pages 43-44. The resulting model was then progressively tested and refined by applying variations on Popper's tests 1-3 for hypotheses and theories.

	Tasks	Activities
1	Identifying and classifying relevant theories, practices, research and development relating to training for CAD in building surveying and selected construction related practices.	**1a** Literature search. **1b** Analysis of key texts, journal and periodical articles, published research findings. **1c** Discussions with key agencies and personnel representative of practitioners and suppliers of CAD systems and services.
2	Quantifying existing use of CAD systems in UK building surveying practice and probable changes during subsequent 5 years: • Types of system deployed. • Applications made. • User characteristics. • Practitioner's perceptions of training.	**2a** Analysis of: • Key texts, journal and periodical articles. • Data from existing surveys. **2b** Discussions with key agencies and personnel. **2c** Postal survey of UK building surveying practices and analysis of results.
3	Identifying and analysing CAD training and other needs, opportunities and constraints for building surveying practice.	**3a** Critical review of data collated in activities 1a-2c, above, 4a-b below, and concurrent instruction.
4	Strand 1 Generating an alternative instructional model for achieving relevant learning objectives. Strand 2 Developing, testing and assessing methods to implement the alternative model.	**4a** Analysis and synthesis of, induction and deduction from results in activities 1a-3a, above. **4b** Generation, validation, implementation and evaluation of prototype courseware for: • Optimising existing methods. • Individualising task-based learning. • Extending instructional methods. • Automating training needs analysis, planning and design. • Integrating computer-based and interpersonal methods for individualised instruction.
5	Formulating conclusions and recommendations.	**5a** Reviewing, synthesising and developing information and results from activities 1a-4b, above.

Fig. 1 Summary of methodology for the research programme

Strand 2 was to develop, test and assess corresponding instructional methods for implementing the alternative model and involved designing, constructing and appraising a series of prototypes.

Task 5 was to formulate conclusions and recommendations from the investigation. For this purpose provisional outcomes were assembled in handwritten and digital notes as they emerged during the research programme, and later used to assemble a preliminary conclusions and recommendations section for the draft thesis. The draft was then comprehensively reviewed to index, consolidate and cross-reference all pertinent concluding content using proprietary spreadsheet software, and to prepare a synopsis. Conclusions and recommendations were then finalised in the thesis by reference to the structured worksheet and summary document.

Work on two or more of the tasks outlined above proceeded concurrently at various times to accommodate limitations on contiguous research time[1], fluctuations in rates of progress with particular tasks, and achieve a productive balance between routine and more demanding activities. Individual research activities are discussed in more detail on pages 23-54.

2.2. Literature search

The literature search combined on line interrogation of specialist databases and academic library catalogues, with manual searching of the following types of hard copy sources:

- Glossaries and handbooks.
- Bibliographies.
- Reviews and conference proceedings.
- Abstracting and indexing services.

1 The research programme was undertaken concurrently with full-time employment as a senior lecturer in information technology in the Department of Building Surveying, and subsequently the School of Architecture, at De Montfort University. Major reorganisation of the institution and its modular system for learning, teaching and assessment occurred throughout much of this period.

- Specialist periodicals
- Research directories
- Miscellaneous publications.

Six specialist on line databases were selected and interrogated on line from De Montfort University Library:

- Acompline
- Architectural Database
- BRIX
- ICONDA
- INSPEC
- ERIC

An outline of each database and representative search pattern was included in the Transfer Report (Watts, 1993). Update searches were made periodically to identify recent additions to the databases. Lists of sources scanned by providers of on-line databases were compared with periodical lists for selected academic libraries and other specialist information services. (BRE, 1991. London Research Centre, 1992. VNU Publications, 1992). Backcopies of appropriately titled journals not covered by on-line searches were scanned manually.

University libraries were searched for relevant non-periodical literature through public access catalogue services (OPACS), (University of Sussex, 1991). Text files of bibliographic records downloaded through the Joint Academic Network (JANET) were merged with a purpose-created bibliographic database using proprietary spreadsheet software for intermediate processing.

2.3. Analysis of key sources

Information identified in the literature search was classified using up to five levels of detail in an extendible numeric system. Desktop publishing (DTP) software was used initially to produce compact alphanumeric and graphical records. Print-out from resulting digital files and extracts for source documents provided a collection of structured information for subsequent visual inspection, extraction, analysis and presentation. Experimental use was also made of hypertext software[1] to collate observations, ideas, concepts and generalisations. Summary records were stored in database files, constructed using proprietary software, with tables for:

- Applications of CAD and associated software systems.
- Bibliographic sources.
- CAD training methods and agencies.
- Theories of instruction and learning.
- Terms and definitions.

2.4. Contact with representative agencies and personnel

Contact was made by letter, telephone, facsimile, Internet and face-to-face meetings with representative personnel from a range of relevant types of organisation:

1. Private building surveying practices.
2. Property and building surveying departments of:
   - Central and local government.
   - Commercial organisations.
   - Health authorities.
   - Housing associations.
3. Suppliers of CAD systems and associated services:
   - Software developers of various sizes and market share.
   - Specialist bureaux.
   - Developers and suppliers of training software systems.
   - Authorised training centres.

1 HyperShell from Text Technology Ltd. (1991).

4. Research organisations specialising in investigating commercial provision and use of information technology.

A list of organisations contacted was included in the Transfer Report (Watts, 1993, pp11-12).

Building surveying practices and departments

The primary reason for contacting private building surveying practices, and the property and building surveying services of other organisations, was to discuss CAD requirements and provision. Contacts were mainly identified through associations of the Department of Building Surveying and Leicester CAD Centre at De Montfort University. In some cases contact occurred during design, delivery and follow-up to CAD training, including for the British Shoe Corporation, Leicestershire County Council and the Welling Partnership. In such cases information for the investigation was assembled through normal interaction between client and service provider, with supplementary observations and note-taking from meetings and training events. In other cases contact was made specifically to discuss aspects of the research programme and notes were made during, or immediately after the event.

Suppliers of CAD systems and associated services

Close contact was maintained during the data gathering stages of research with suppliers of CAD systems and associated services. Such interaction was primarily to ensure awareness of commercial rationales and procedures, in particular for CAD software development, marketing, distribution, regulation, associated education and training activities. The main initial source was GABLE CAD Systems Ltd. of Sheffield through software development links with the Leicester CAD Centre. Subsequent dialogue with GABLE executive and technical staff followed in the role of client, service provider, collaborative training provider and researcher. User Group meetings for the company's 4D Series CAD software provided additional opportunities to discuss application and training issues with informed personnel from a range of private practice and public sector organisations.

As market conditions changed, and Autodesk Inc. emerged as the dominant supplier of software to the world's CAD market, Autodesk Ltd. became the primary commercial contact via the UK company's headquarters in Guildford. Dialogue was sustained through the capacity of Leicester CAD Centre as an

Autodesk Authorised Training Centre for the AutoCAD and AutoCAD AEC software systems, and an Authorised Developer of associated software and services. Regular liaison occurred by letter, telephone, and visits to and from the Autodesk Education Department. Update training was also undertaken at Guildford with personnel from other Authorised Centres for successive releases of the AutoCAD and AEC software. The author also attended annual forums organised by Autodesk for its UK Authorised Training Centres with contributions from the company's executive, technical and administrative staff.

Between 1991-3 the author had additional access to Autodesk's education and training policies, practices and staff as a member of the authoring group for the City and Guilds of London Institute (CGLI) (1993) Scheme 4351-06 : Using AutoCAD AEC for the Built Environment, sponsored by the software developer. This work required close involvement with CGLI strategy and methods for training and assessment in the use of information technology. It provided opportunities to visit and observe practices and procedures at Autodesk Authorised Training Centres in East Leake, Leeds and Hartlepool where three of the co-authors worked. Following the CGLI project, productive contact also occurred with the CAD editor at the International Thomson Publishing Co., a strategic partner with Autodesk through its Autodesk Press in publishing paper-based and digital educational resources for CAD.

Research organisations

Contact occurred with a variety of research organisations during data gathering stages of the research programme. Early contact was made and sustained with the Construction Industry Computing Association (CICA) at Cambridge for guidance on contemporary CAD-related research. Clarification was also sought on sample selection and question sets used for its successive surveys of uptake and application trends for information technology in the UK construction industry (CICA, 1987, 1990, 1993). Advice on relevant projects, publications, seminars and demonstrations followed periodically.

Contact was made during Task 2 of the programme with commercial research agencies undertaking relevant investigations, for example the International Data Corporation (IDC) and Training Information Network Ltd. (TIN), concerning market trends in the supply and demand for information technology training services. By contrast, however, with the CICA which made its findings available for a modest annual subscription, these organisations engaged primarily in contract research and charged heavily for supplying their reports to third parties. Access to the full text of such documents was consequently limited.

Part-time building surveying students

Throughout the research programme regular contact was maintained in timetabled classes with part-time students of building surveying during their second, fourth and fifth years of a five year course at De Montfort University. Recruited from a wide range of employers across central England, and sometimes beyond, this group of over 100 students was considered representative of trainee building surveyors and their workplaces in the UK during 1991-2000. They provided a regular supply of useful information on requirements, provision, opportunities, constraints and alternative strategies for CAD in building surveying through class discussions, case studies, workplace reviews and use of CAD in their coursework assignments.

2.5. Postal survey of UK building surveying practices

A postal survey of practices was planned originally to update and extend published statistics on the use of CAD in building surveying. However, as data gathering proceeded from texts, journals, periodicals and existing surveys in Task 2, it became clear that sufficient data were unlikely to have been gathered previously. Consequently the intended update survey became the primary statistical source for the investigation. In this context, and because of the diverse nature of building surveying practice, considerable time was spent identifying a representative sample from which to gather responses.

The population of initial interest included any UK organisation employing one or more chartered building surveyor(s). The Department of Mathematical Sciences at De Montfort University advised that a statistically valid sample should be selected at random from a survey population stratified by type and size of organisation, and geographic distribution. The Royal Institution of Chartered Surveyors (RICS) was contacted to investigate the possibility of selecting a suitable sample from its records. Access was offered to the RICS membership database as the most likely source. Unfortunately closer inspection of these records revealed insufficient information on type and size of workplace to select the required sample[1]. To overcome these difficulties an alternative, but considerably more time consuming, method was devised to identify the sample. Details for 4796 practitioners were accumulated from published sources by the method summarised in Fig. 2 and recorded in a suitably structured database (Fig. 3, p30).

1. Extract from published sources and make a database record for each building surveyor with a UK address. Mark each entry with a randomly generated code.

↓

2. Classify records by workplace type.

↓

3. Sort database of total population by workplace type, name and location to identify representation of workplace type and location in the total population.

↓

4. Sort total population by random code and select every 25th record until sample of 200 practices is representative of identified strata.

Fig. 2 Method for selecting a stratified random sample of UK building surveying practices

1 Telephone conversations in January 1992 with Howard Land, Director of Education and Membership, Royal Institution of Chartered Surveyors (RICS), Coventry.

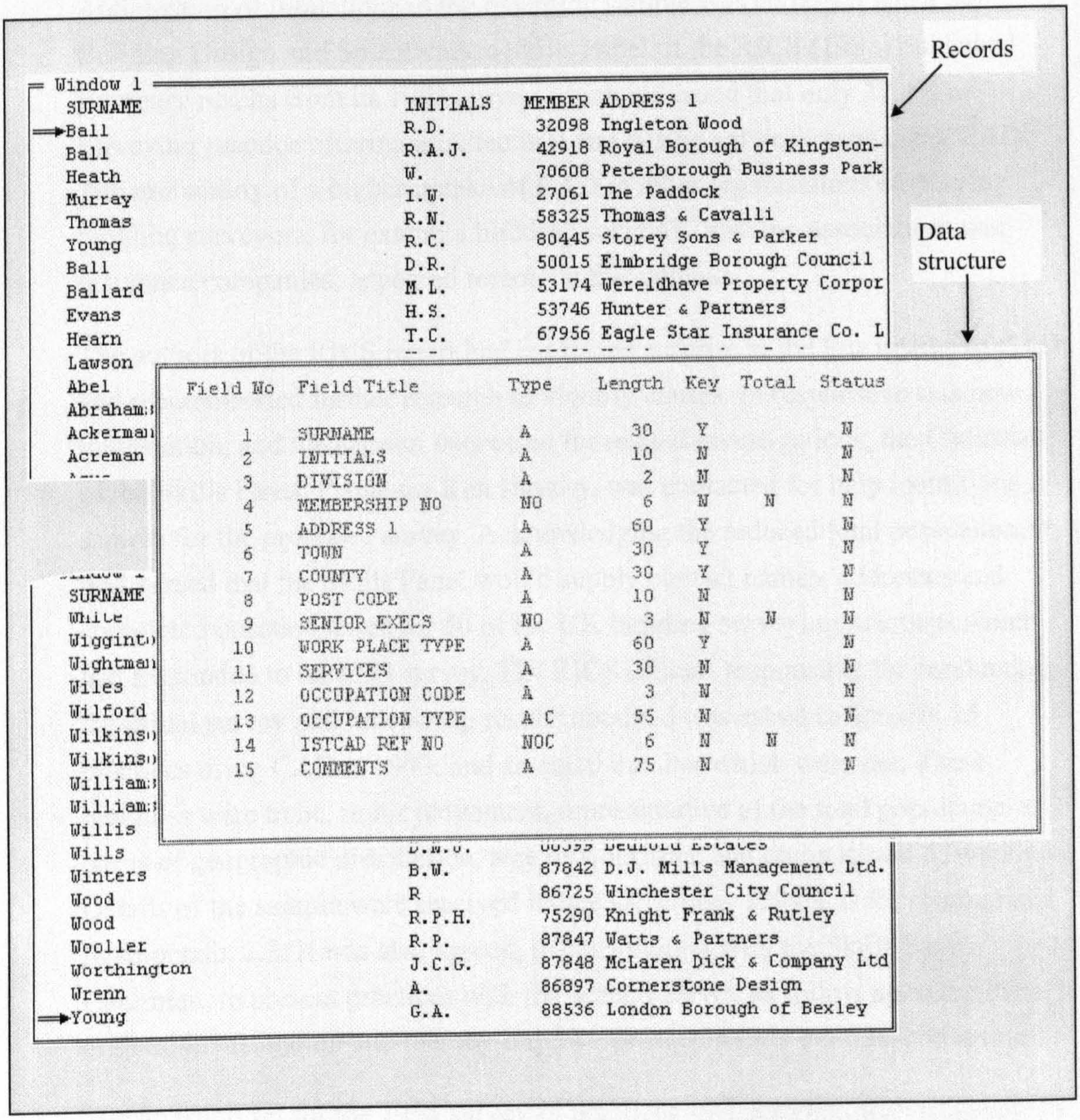


Fig. 3 Database of UK building surveyors for identifying a survey sample

By this time, however, discussions with practitioners had indicated that the uptake of CAD in organisations whose staff included building surveyors was probably low. Proceeding with the revised method was likely to have provided reliable data on the overall uptake of CAD in a wider interpretation of building surveying practice, and substantial data on perceptions of need in organisations without CAD. However, considerably fewer responses were likely to have informed the core concern with applications and skills in organisations actually using the technology.

Anticipation of limitations in the emerging sample was endorsed when the Building Design and Specification Skills Panel of the RICS (1993) published summary results from its 1993 survey which indicated that only 37.4% of surveying practice offering architectural and design services were using CAD. The probability of a higher uptake of CAD in other organisations employing building surveyors, for example building societies, housing associations and insurance companies, appeared remote in this context.

The authors of the RICS report had expressed surprise at the low uptake of CAD and recommended further research to identify causes. In response to this new information, and the support expressed for related investigations, the Chairman of the Skills Panel, Professor Ken Hawley, was contacted for help identifying a sample for the proposed survey. Acknowledging the reduced total population, it was agreed that the Skills Panel would supply contact names, addresses and completed questionnaires for 50 of the UK building surveying practices which had responded to its 1993 survey. The RICS officer[1] responsible for conducting the initial survey and processing results obtained was asked to identify 25 practices using CAD at 1993, and an equal number which were not. These practices were to be, in his judgement, representative of the total population in terms of geographic distribution, size of workforce and composition of workload. Details of the sample were received in late December 1994 and are summarised in Appendix 2.3. It was also agreed, in consultation with the Skills Panel Chairman, to present practices with the second survey as follow up to the Panel's original investigation and thereby improve prospects for a good response rate.

The question set for the 1995 survey of practices was designed with reference to Romiszowski (1984) who categorised the causes of problems experienced in organisations as deficiencies in:

- Materials.
- Methods and / or equipment.
- Human performance.

1 Richard Turton, Building Surveying Division, RICS, Great George Street, London.

Variables	Components	Question in survey	
		1993	1995
Size and composition of practice	Range of contract values, as context for expenditure on CAD systems, training policies and practices	7	
	Number of offices, as context for data exchange practices		1.2
	Number and type of staff, as context for use of CAD systems		1.3
Types of work undertaken		6	
Software systems used in addition to CAD			2.1
Selection of CAD system(s)	Timing and nature of initial CAD use		3.1
	Relative significance of information sources when selecting the current CAD system		3.2
Current use of CAD	Specification of hardware and software		4.1
	Initial and current reasons for using CAD		4.2
	Availability and frequency of use of CAD functions		4.3
	Frequency of use of CAD by type of staff		4.4
	Incidence of in-house CAD services		4.5
	Frequency and trends in use of CAD for specific purposes		4.6
	Type and frequency of benefits from CAD		4.7
	Type and frequency of problems with CAD		4.8
System management	Distribution of CAD-related tasks by type of staff		5.1
	Provision of maintenance agreements by type of CAD resource		5.2
	Priorities for future use of CAD		5.3
Training policies and practices	Timing of CAD training by type of staff		6.1
	Methods used for CAD training		6.2

Table 1 Variables in the 1995 survey for practices using CAD

Variables of interest (Table 1, p32 and Table 2) were identified by the author to clarify relevant requirements for CAD in manually-based practices, and deficiencies in those already using the technology. References in columns three and four of Tables 1 and 2 are to sections in the questionnaires, shown in Appendix 2.1, and used for data collection.

Variables	Components	Question in survey	
		1993	1995
Size and composition of practice	Range of contract values	7	
	Number of offices		1.2
	Number and type of staff		1.3
Types of work undertaken		6	
Software systems used			2.1
Workload	Composition and trends		3.1
	Drawing activity by type of staff and frequency		3.2
Potential use of CAD	Interval since CAD was last considered		4.2
	Relative significance of information sources when selecting the current CAD system		4.3
	Previous use of CAD by type of staff		4.4
	Reasons for not using CAD		4.5

Table 2 Variables in the 1995 survey for practices not using CAD

The postal survey was undertaken between February and April 1995 in collaboration with a final year building surveying student at De Montfort University[1]. Distribution of questionnaires was followed up with letters and telephone calls encouraging practices to respond. Data from returned questionnaires were combined in a suitably structured database (Fig. 4, p34) with

1 Oliver Trice, Bsc (Hons) Building Surveying, Year 3, 1994-5, supervised by the author in an investigation of methods for implementing CAD in building surveying practice for his final year dissertation.

corresponding responses to the 1993 RICS survey, as supplied by the Skills Panel.

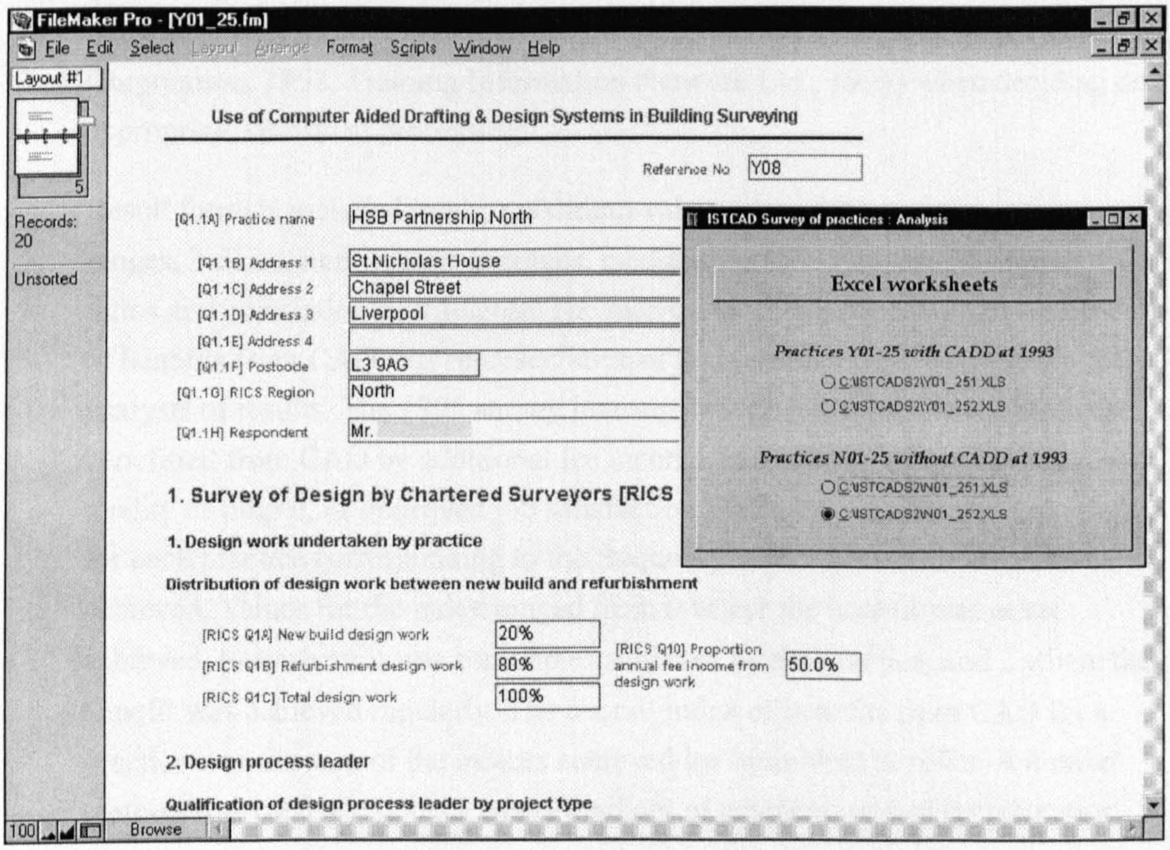


Fig. 4 Database and spreadsheets for collating and analysing responses from the 1993 and 1995 surveys of practices

Responding practices from the sample were classified for comparative analysis by size of the professional and technical workforce as shown in Table 3. The workforce characteristics determining classification of respondents as small, medium sized or large practices were decided partly by consideration of the sample, supplied as representative by the RICS, and also by reference to Richardson's (1994, p14) survey of 78 practices in the north of England.

Total professional & technical staff	Classification
1-4	Small
5-14	Medium
15+	Large

Table 3 Classification of practices by number of staff

Relevant data sets were then exported from the database as tab-delimited text files for statistical analysis and generation of bar charts, pie charts and line graphs in proprietary spreadsheet software. Reference was made to results published from other surveys (CICA, 1987, 1990, 1992, 1993. International Data Corporation, 1992. Training Information Network Ltd., 1991) when deciding on appropriate statistical processing.

Result formats included totals, maximum values, percentages; frequencies, ranges, indices, rank orders; averages, medians, modes, standard deviations; ratios and correlation coefficients. The method used to calculate an overall index of benefits from CAD was representative of that used for other purposes in the analysis of results. The 1995 survey investigated the extent to which practices benefitted from CAD by additional fee income, improved productivity, increased quality of output, or improved job satisfaction. An index number was recorded for each practice corresponding to the frequency with which each benefit was achieved. Values for the index ranged from 0 where the benefit was never achieved, to 1 where it was sometimes achieved by the practice, and 2 where the benefit was achieved regularly. The overall index of benefits from CAD for a practice was the sum of the indices achieved for individual benefits. A similar method was used to calculate overall indices of problems and of collaboration.

Interpretation of results was facilitated with a purpose-designed multimedia application (Fig. 5, p36). The software enabled charts and graphs produced during analysis of numeric data in a spreadsheet to be assembled in a random access library for display with corresponding notes stored as external text files. Notes were refined, indexed and cross-referenced through hyperlinks in the application to identify connections between results, and their significance. Text files were subsequently imported into a DTP system for assimilation with the main thesis document. Design and construction of the application for this purpose also provided opportunities to familiarise with a set of software tools central to subsequent research and development of alternative models and methods, as described on pages 43-53.

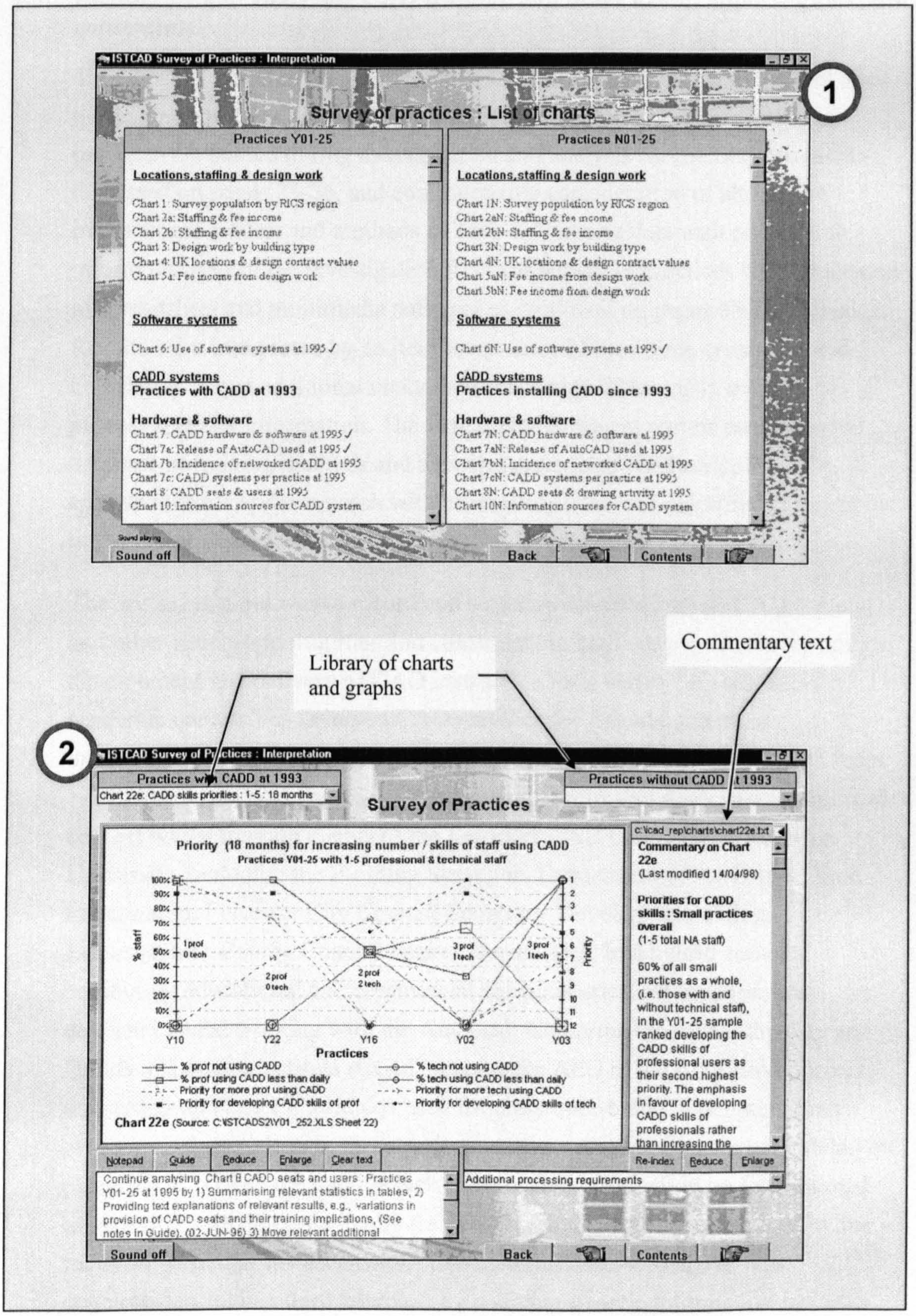


Fig. 5 Multimedia application for interpreting survey results

(Source: c:\icad_rep\survey1.tbk)

2.6. Identifying and analysing CAD training and other needs, opportunities and constraints

Task 3 of the research programme involved identifying CAD training and other needs, opportunities and constraints in building surveying. This work was productively started during data collation and analysis for the first two tasks discussed on pages 23-36, and continued into consideration of alternative instructional models and methods in Task 4. Numeric data with potential to inform this part of the investigation from the survey of practices were processed in spreadsheet and multimedia software as described on pages 35-6, for Task 2. Results were interpreted by an iterative process of browsing, reviewing and annotation. Three additional methods were used to distinguish, collate and process relevant information. The first approach was to review records in the database of training methods and agencies assembled for Task 1, for correspondence and mismatch with instructional theories identified at this point in the research, and results from the survey of practices.

The second method was to record and structure observations on CAD training and other needs, opportunities and constraints in hard copy notes during design, development and delivery of CAD instruction for a variety of uses. In an academic context this involved CAD modules for full and part-time undergraduate students of building surveying at De Montfort University (Years 1-3 full-time, and 2-5 part-time). Observations were also made in a commercial context whilst training clients of the Leicester CAD Centre at De Montfort University, including the Building Surveyors Department of the British Shoe Corporation, Leicester City Council Economic Development Unit and Leicestershire County Council Estates Department. In a hybrid context, combining educational and commercial characteristics, information was collected whilst working with the Autodesk Authoring Group for the City and Guilds of London Institute (CGLI) scheme for AEC in the Built Environment, referred to on page 27. Methods used for classroom-based experiments and associated observations in these various contexts are described in more detail on pages 46-47. Given the relative lack of published information on instructional models and methods specifically for CAD training, referred to on page 20, the focus on particular instances in the two methods described above was counterbalanced in a third approach by collating generic information from the literature on training problems, techniques and gaps in knowledge.

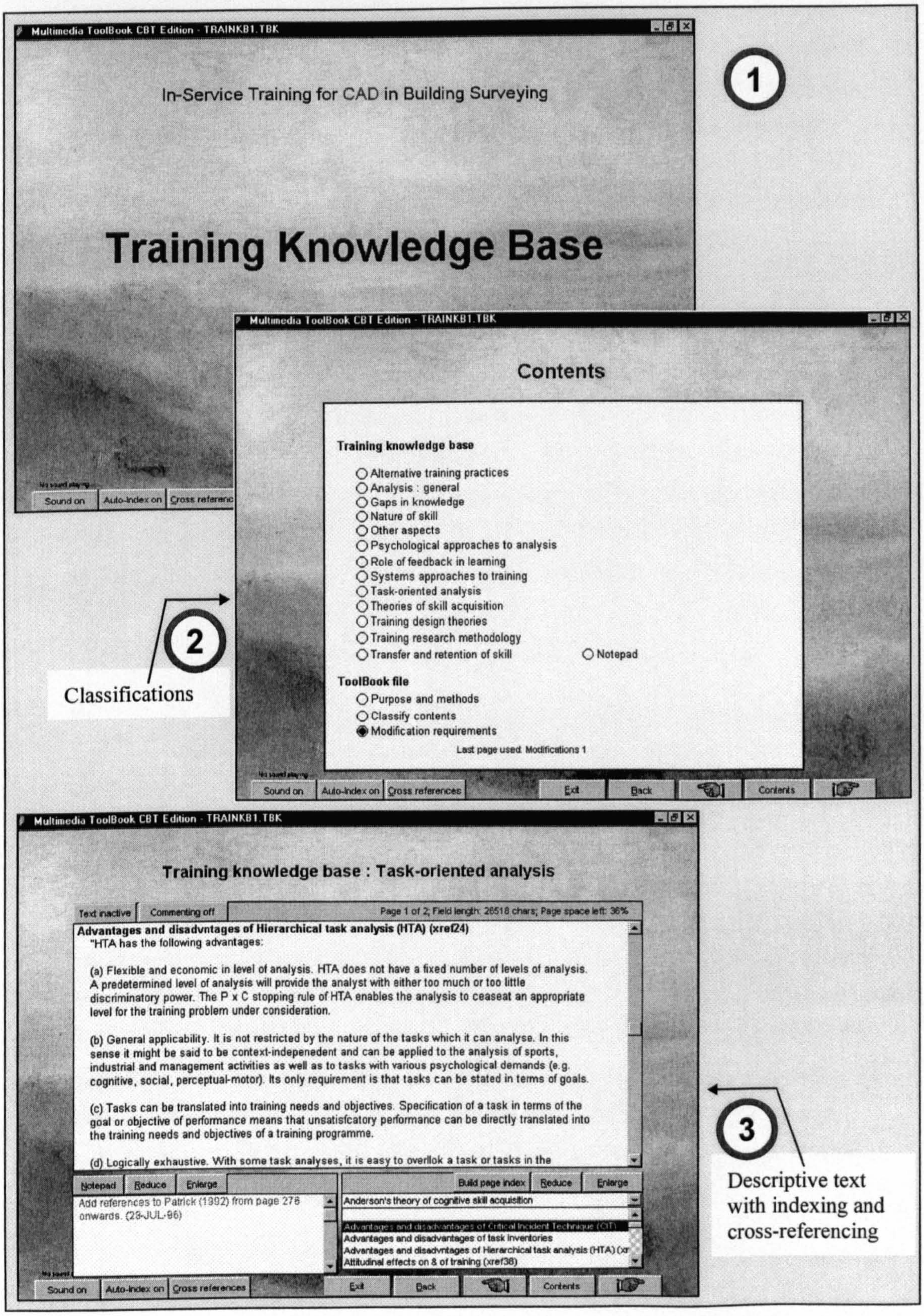


Fig. 6 Multimedia application for collating training problems, solutions and gaps in knowledge

(Source: c:\icad_rep\survey1.tbk)

Benefits of the software tool (Fig. 5, p36) produced to assemble and interpret statistical results from the survey of practices suggested a similar method for collating relevant information. A training knowledge base (Fig. 6, p38) was constructed with the same software tools and used to assemble, classify, supplement and cross-reference information identified through the literature search. The resulting knowledge base was intended to support generation of alternative models and methods later in the research programme.

2.7. Developing and testing alternative instructional models and methods

Overall process and chronology for Task 4

Developing and testing alternatives to conventional training in Task 4 followed two parallel strands of investigation which, with formulating conclusions and recommendations, proved the most intellectually and technically challenging aspects of the research programme. Strand 1 required generation and testing of an alternative instructional model as an optimal process for equipping in-service trainees to achieve relevant learning objectives. As research progressed the substance of relevant learning objectives could be summarised as:

- An understanding of relevant CAD system(s) and their cost-effective application to authentic tasks in building surveying practice.
- The capacity for self-directed learning to extend and update CAD knowledge and skills in the future.

Strand 2 was the logical concomitant of Strand 1 and involved developing, testing and assessing corresponding instructional methods. Development and testing for Strands 1 and 2 was an iterative process based upon an action research methodology after Cohen and Manion (1989). Variations on Popper's (1959) deductive tests 1-3, regarded as the most rigorous available for hypotheses and theories and modified to reflect the nonscientific character and purposes of instructional modelling, provided primary evaluation tools for stages 6-8 of Cohen and Manion's process (Appendix 3):

Test 1: Logical comparison of conclusions from the model amongst themselves to test the internal consistency of the system.

Test 2: Investigation of the logical form of the model to determine if it has the character of an instructional theory, or whether it is tautological.

Test 3: Comparison with other models to determine whether the alternative would constitute an advance in CAD training practice should it survive all other tests.

Designing, constructing and testing prototypes for key components of the developing model was regarded as an acceptable alternative to strict use of the scientific method in Popper's fourth test which requires empirical application of conclusions derived from a theory. The essential mechanism for the iterative process undertaken is summarised in Fig. 7, page 41.

Research and development for Task 4 proceeded in five phases, as summarised in Table 4, and produced 11 evolutions of an alternative instructional model (column 3). Component activities for R & D Phases 1-5 are summarised in Table 5, pages 42-43.

R & D Phase	Description	Model version
1	Optimising existing methods.	-
2	Individualising task-based learning	1a - d
3	Extending instructional methods	2a - c
4	Automating training needs analysis, planning and design	3a
5	Synthesis: Integrating computer-based and interpersonal methods for individualised instruction.	3b, 4a-b

Table 4 Five phases of research and development (R & D) for alternative instructional models and methods

Work began in Phase 1 with revising existing instructional methods to try and remedy problems identified through the literature search, discussions with representative agencies and personnel, and preliminary observations in the classroom. The principal activities undertaken for this purpose are shown in column two of Table 5, pages 42-3. The role of instruction in relation to problem-solving in the practice was then established in Versions 1a and 1b of the model, primarily by reference to Romiszowski (1984). Implications from this work were drawn for data collection and subsequent analysis in the survey of practices described on pages 28-36.

Strand 1

Development of an alternative instructional model

(Activities 3.1, 3.2, 3.4, Table 5, pp42-43)

Representation of the model's form in flowcharts and multimedia.

Application of variations on Popper's tests 1-3:

1. Logical comparison of conclusions from the model amongst themselves to test internal consistency of the system.
2. Investigation of the logical form of the model to determine if it has the character of an instructional theory, or whether it is tautological.
3. Comparison with other models to determine whether the alternative would constitute an advance in CAD training practice should it survive all other tests.

Modification to remedy defects and integrate enhancements.

Strand 2

Developing, testing and assessing implementation methods

Designing, constructing and appraising prototype components of the instructional model.

(Activities 3.1, 3.3, 3.5, Table 5, pp42-43)

Fig. 7 Essential process for testing and developing alternative instructional models and methods

Whilst developing and testing alternative instructional models and methods in Task 4 the data gathering components of Tasks 1-3 continued so that additional information on requirements, best practice and problems with other methods of CAD training was available for consideration. Results obtained from the survey of practices by the techniques described on pages 35-6 were reviewed in association with subsequent versions of the instructional model to refine interpretations of significance and alternative proposals for training (Activities 2, 3.2, 3.3, 3.4, 3.5 in Table 5, pp42-43).

Activities	R & D Phases for Task 4: 1 Optimising existing methods	2 Individualising task-based learning	3 Extending instructional methods	4 Automating training needs analysis, planning & design	5 Integrating computer-based & interpersonal methods for individualised instruction
1. Collating additional information on requirements, theories and practices by:					
1.1. Literature search and analysis of sources.	✓	✓	✓	✓	✓
1.2. Collating knowledge base of generic training problems and gaps in knowledge.			✓	✓	✓
1.3. Discussions with representative agencies and personnel.	✓	✓	✓	✓	✓
2. Analysis of results from survey of practices, including additional ad hoc processing for specific purposes.			✓	✓	✓
3. Iteration of:					
3.1. Observing trainees and students in class.	✓	✓	✓	✓	✓
3.2. a) Synthesising requirements, empirical data, theories and methods.	✓	✓	✓	✓	✓
b) Representing alternative models in:					
3.2.1 2D schematic	✓	✓	✓	✓	✓
3.2.2 Multimedia schematic			✓	✓	

Activities	R & D Phases for Task 4				
	1	2	3	4	5
	Optimising existing methods	Individualising task-based learning	Extending instructional methods	Automating training needs analysis, planning & design	Integrating computer-based & interpersonal methods for individualised instruction
3.3. Identifying methods to implement instructional model.	✓	✓	✓	✓	✓
3.4. Applying Popper's deductive tests 1-3 to the alternative model and methods.	✓	✓	✓	✓	✓
3.5. Developing and practical testing key components of the model.					
3.5.1 Prototyping	✓	✓	✓	✓	✓
3.5.2 Classroom experiments	✓	✓	✓		
3.5.3 Examining outcomes from trainees	✓	✓	✓		
3.5.4 Analysing feedback from clients	✓	✓			

Table 5 Activities for research and development of alternative instructional models and methods in R & D Phases 1-5

Deriving the basis for an alternative instructional model

The initial version (1a) of an alternative instructional model was synthesised from results of processing sources identified through the literature search, discussion with representative agencies and personnel (See pages 25-28), and the practical experiments to optimise existing training methods referred to in the preceding paragraphs. The process for this operation involved three main steps:

1. Assigning to separate layers in a 2D CAD file the form, content, underlying theories and assumptions of the most developed methods thus far identified[1].

2. Overlaying the components represented in Step 1 with inadequacies identified in the literature search, discussions with practitioners, suppliers, and observations in the classroom.

3. Explaining and supplementing the schematic resulting from Steps 1 and 2 by reference to theories and practices identified in the research programme from any source or method.

Representing the model in multimedia

Representing the developing model in Phases 2-4 as a two dimensional schematic of the type described above was found to limit recognition and expression of interrelationships, theories, and mechanisms for practical tests. These constraints were substantially overcome using multimedia authoring software to hyperlink diagrammatic representations with relevant analysis and proposals (Fig. 8, p45). Conversely, as the model was consolidated in Phase 5, multimedia proved less conducive to communicating the overall schematic, and a multilayered flowchart created using 2D presentation software became the core means of displaying proposals for conceptual testing.

Deriving prescriptions from published instructional theories

Although no comprehensive analysis of instructional models for CAD training had been identified in the literature search, theorists were progressively found whose work appeared either to corroborate proposals from the research programme, suggest the means for their improvement, or indicate potential routes to their implementation. Assimilating these sources was, however, variously problematic, as discussed in the Transfer Report (Watts, 1993, para 7.3.1, p29).

1 CAD in Building Surveying: Introductory, Intermediate and Advanced training modules for Bsc. (Hons) Building Surveying students at De Montfort University. Courseware was commended as runner-up in 1993 IBM United Kingdom Prize for Information Technology Skills, (The Partnership Trust (1993).

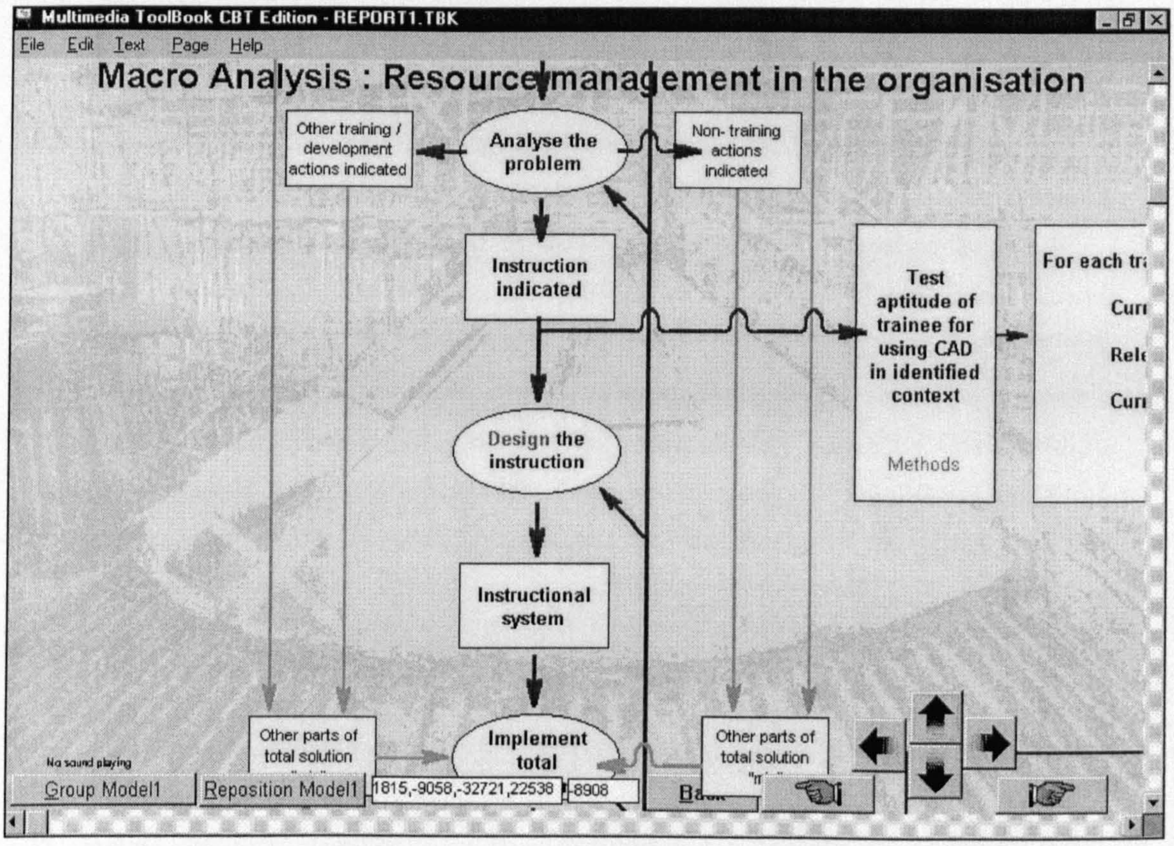


Fig. 8 Representing the developing instructional model in multimedia

Authors which did make prescriptions, for example Goldfield (1987), Bower and Hilgard (1981) tended not to clarify their relationship with published theory. Sources which dealt concurrently with theory and practice, as Gustafson and Reid (1990) observed, rarely provided sufficiently precise advice for direct application to specific practical requirements. These deficiencies were recognised later as examples of the general lack of prescriptions in published educational research, as identified by Romiszowski (1984, p208) and Cohen and Manion (1989, p220), rather than being peculiar to training for CAD. A productive response required acceptance that a range of global unknowns pertain to instruction and learning, and which the Training Knowledge Base described on pages 38-39 was partly intended to document. The search for relevant concepts and techniques continued, with this limitation, through analysis of available instructional theories and practices displaying complementary emphasis. Sources were sought which could elaborate with more prescriptive content on theories already identified. At the same time the search continued for sources offering additional, more prescriptive, theories to those already found.

A further approach used to address the lack of clear prescriptions in published theory involved a variation on the clean-room reverse engineering methodology deployed in developing alternatives to proprietary hardware and software products, and recently summarised by Karellen (2001). For this purpose published sources dealing with theories of apparent potential for the research programme were examined to isolate distinctive features and performance characteristics. Collected technical papers written by individual theorists, and accompanied by pertinent editorial commentaries from other authors, proved particularly useful for this purpose[1]. Specifications prepared by this method were then used to set targets for, and assess progress with, iterative research and development using other activities from Table 5, pages 42-43, to identify techniques capable of achieving comparable outcomes for the specific conditions of training for CAD.

Classroom based experiments and observations

Versions of alternative instructional models and methods developed in R & D Phases 1 and 2, and the first half of Phase 3 (See Instructional Methods 1-3, pages 157-221), were tested where feasible in the classroom with full-time and part-time building surveying students and staff at De Montfort University and with commercial clients of the Leicester CAD Centre. Experimental paper-based learning tasks were developed for this purpose through group work at Leicester CAD Centre using a methodology after Ayerst (1987). Liaison was sustained with Autodesk Ltd. and various of the company's Authorised Training Centres elsewhere in the UK during this work.

Pertinent observations and aspects of discussion from classes were recorded in handwritten notes. These records were subsequently indexed by key subject in the database described on page 25 for retrieval, analysis and supplementing with ideas as they emerged during other parts of the action research programme. (Such notes usefully extended the more structured digital records described on pages 24-5 and the multimedia documents described on page 44.) Selective use was also made of video recording (Fig. 9, p47), although technical problems

1 For both Scandura and Landa as an example the most useful summaries were provided by Reigeluth (1983).

experienced achieving footage of adequate quality from computer screens limited its utility for documenting interaction with the CAD system.

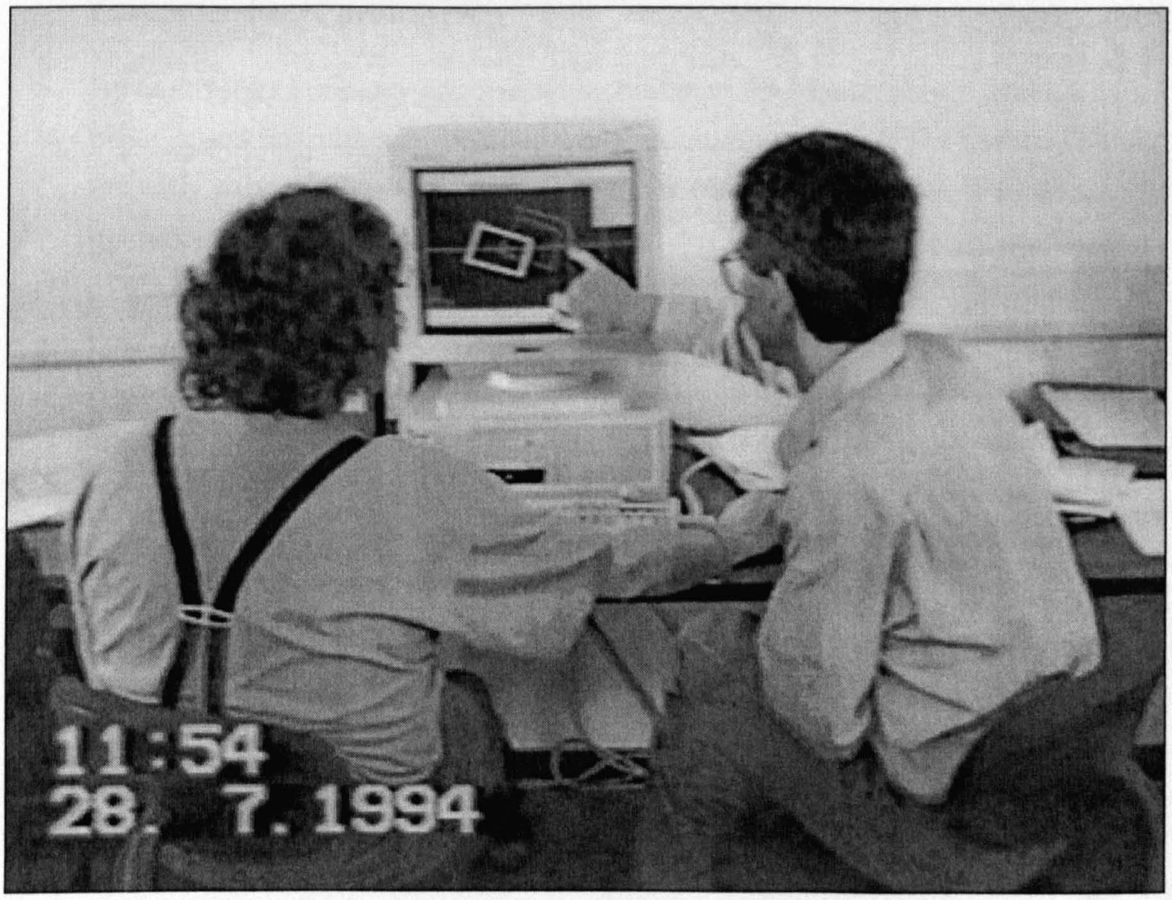


Fig. 9 Video recording of experimental instruction, learning and assessment techniques

Responses to the resulting training were received directly from, and discussed with, full and part-time students at the University, and trainees participating in the courses offered commercially by the Leicester CAD Centre. Feedback from the latter was additionally received from, and discussed with, Autodesk's Education Department. Some clients also collected and discussed feedback from their trainees independently, for example the Economic Development Unit of Leicester City Council did so for a series of training courses commissioned between 1991 and 1993. Later in the research programme a World Wide Web-based questionnaire was used for anonymous collection of feedback from full and part-time building surveying students on their experiences with instructional methods for CAD in undergraduate modules at the University. Data received were processed using purpose written Visual Basic routines in proprietary spreadsheet software. These mechanisms, designed and developed in collaboration with the School's network technician, are described in more detail in Watts and Ashton (1996, pp178-9)).

Computer-based prototyping

By contrast to a primary concern with combinations of interpersonal and paper-based instructional methods when prototyping for R & D Phases 1, 2 and the early parts of Phase 3 described in pages 46-7, subsequent work focused upon computer-based methods for various reasons. The inherently digital nature of CAD, and costs implied in prescribing individualised instruction and learning through manual and interpersonal methods, indicated computer-based solutions. Additionally, as Patrick (1992) observed, investigating such provision would ensure rigorous analysis of requirements and consideration of alternatives. From the second half of R & D Phase 3 onwards, therefore, the author functioned in roles normally undertaken by team when developing instructional software (See for example Microsoft (1993, p10) and Asymetrix Corporation (1996, p30)). The various functions included analyst, writer, editor, proofreader, user-interface designer, graphic designer, audiovisual technician, developer-programmer and tester. In doing so reference was made to previous work in art and design contexts where the requirement to fulfill a multifunctional role in developing concepts, processes and artifacts is more common.

An essential premise for computer-based prototyping was to produce software adequate for testing concepts, as distinct from applications designed and constructed to satisfy the operational standards of commercial systems. Although the emphasis was on investigating viable computer-based mechanisms for implementing the alternative instructional model it was subsequently accepted, notwithstanding costs, that its prescriptions might only be achievable by manual and interpersonal methods, or by a hybrid of these mechanisms with digital solutions. The significance of the software development process for achieving rigorous analysis consequently became increasingly important in the R & D process. The model and methods specified from the second half of Phase 3 until the end of Phase 5 increasingly exceeded capabilities in the research programme for producing robust prototypes. Scope for practical testing in the classroom at De Montfort University with undergraduate students, or clients of the Leicester CAD Centre was consequently limited.

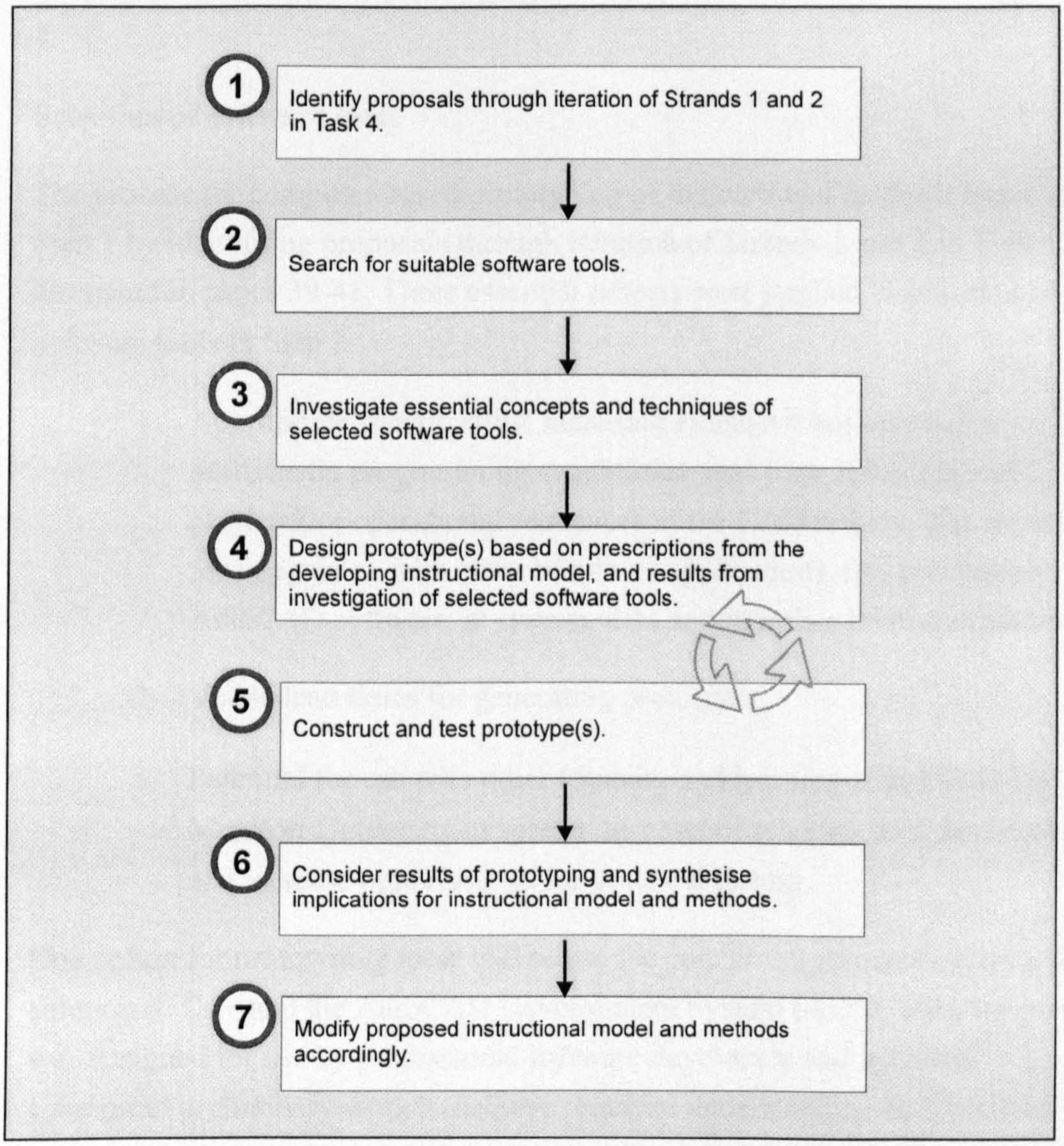


Fig. 10 Core process to prototype computer-based components for instructional models

Computer-based prototyping of key components from the developing instructional model in R & D Phases 3-5 followed a core process for software design and development summarised in Fig. 10 which effectively details the activity indicated for Strand 2 in Fig. 7 on page 41. Steps 2-7 combined top-down analysis with bottom-up experimentation. As elsewhere in the programme, however, research activity did not follow a strictly linear route and Step 2 overlapped Step 3, Step 4 was partially concurrent with 5, and Step 6 overlapped Step 7. Essential features of methodology for this part of the research programme are discussed below. A more detailed account of software development methods for prototyping in R & D Phases 3-5 is given in Appendix 4.

Selection of software tools

The process for computer-based prototyping of instructional methods began in Step 1 by identifying proposals through iteration of Strands 1 and 2 in Task 4, as discussed in pages 39-41. Three essential criteria were applied in selection of software tools in Step 2:

1. Appropriate functionality, including extensive but accessible multimedia programming capabilities, real-time recording and playback of operational sequences in the CAD system. The capacity for integration with other Windows applications, and particularly AutoCAD software, at system, data and interface level was essential.

2. Viable lead times for generating prototypes.

3. Potential for use with other teaching and learning activities at De Montfort University to spread the costs of relevant staff development and increase opportunities for practical testing.

One option for prototyping tools was to use the concurrent standard commercial solution of C++ and the AutoCAD Development System (ADS). This, however, was designed for use by professional software developers and involved substantial preliminary work to achieve requisite understanding and familiarity with essential concepts and techniques. An alternative was to integrate AutoCAD and its native AutoLISP programming language with proprietary tools for multimedia authoring, knowledge engineering and real time screen recording using Microsoft's Dynamic Data Exchange protocol (DDE). Guidance on an appropriate route was sought from academic and technical staff at De Montfort University with experience in commercial CAD applications, or courseware development. Specialist technical journals and the World Wide Web (WWW) were searched for information on alternatives. Software developers and suppliers identified by these methods were then contacted for information and advice.

Ref	Name	Function	R & D Phase		
			3	4	5
			Extending instructional methods	Automating training needs analysis, planning & design	Integrating computer based & interpersonal methods for individualised instruction
1	AutoCAD menu customisation and Dialogue Control Language (DCL)	Interface customisation	✓		
2	AutoLISP	Programming language for AutoCAD	✓		✓
3	Authorware	Multimedia authoring system	✓		
4	XpertRule	Knowledge based systems generator	✓	✓	✓
5	Microsoft Dynamic Data Exchange (DDE)	Systems integration protocol	✓	✓	✓
6	Asymetrix ToolBook	Multimedia authoring system	✓	✓	
7	Lotus ScreenCam	Screen capture and display system	✓		
8	FrontPage 98	World Wide Web authoring system	✓	✓	
9	Microsoft Help Workshop and Compiler	Online help authoring system	✓		
10	Microsoft Access	Relational database management system		✓	✓
11	Microsoft Visual Basic	Programming language		✓	✓
12	Microsoft Open Database Connectivity (ODBC)	Database management protocol		✓	
13	Standard Query Language (SQL)	Database management language		✓	
14	WinSpeech	Speech synthesiser		✓	
15	Asymetrix ToolBook : CBT	Multimedia authoring system for computer based training			✓
16	Asymetrix ToolBook Database Connection	Database management extension for Asymetrix ToolBook			✓
17	Paradox	Database management system			✓

Table 6 Software tools to prototype alternative instructional models and methods

The second route, involving integration of a set of proprietary software tools via DDE, was subsequently chosen to reduce lead times and maximise opportunities for symbiosis between Strands 1 and 2 (pp40-41). Software tools used for subsequent prototyping are summarised in Table 6.

Of the nine software tools used in R & D Phase 3 (Items 1-9 in Table 6, page 51) none had been previously used by the author. Although expertise was available locally for some of these systems, it did not extend to techniques for achieving the required integration. Relevant knowledge and ability were necessarily developed through a combination of practical experiments with use of published hard copy manuals, online help systems and web-based resources including knowledge bases, bulletin boards, lists of frequently asked question (FAQs) and discussion groups. Opportunities were also taken to combine software development in support of other parts of the research programme, for example the multimedia application for interpreting survey results (Fig. 5, p36) and training knowledge base (Fig. 6, p38) described earlier, with developing knowledge and capabilities for prototyping alternative instructional methods. These activities also provided the author with valuable insights into problems of, and options for, learning new software applications in the workplace. Step 3 in the process (Fig. 10, p49), for example, required rapid exploration of essential structure for the different software systems involved, and practical experiments to identify the most relevant application techniques. Experience gained by this work informed the instructional model, in particular proposals for active learning discussed in Section 3.12 on pages 249-273, below.

Integration of software components

As research and development progressed in R & D Phases 3-5 the need to integrate custom-built components with proprietary software applications became fundamental to progress. In R & D Phase 4, for example, the rule processing component of the available knowledge engineering software required read and write access to trainee records in proprietary database software. An appropriate communication channel was initially achieved using DDE but construction of the prototype was unfortunately constrained by inadequate documentation of DDE protocols. As Attar Software (1996, pp183-4) acknowledge, solving problems of this type is often heavily dependent upon characteristics of the tools involved, and the results required by the developer. In such circumstances there is little alternative to self-directed experiments which often prove time-consuming. Subsequent investigation resulted in use of more overt and robust functions from the Standard Query Language (SQL) and Open Database Connectivity (ODBC) protocols. Providing a readily accessible trainee interface to a knowledge base for instructional design later required familiarisation with Visual Basic and a corresponding imperative for use of its DDE functions. Experiments to extend the user interface also involved investigation of available speech synthesising software and familiarising with the WinSpeech system.

Integrating design and delivery of instruction in R & D Phase 5, required additional software capabilities, particularly for assessment and database functions. Suitable provision was found in the Computer Based Training (CBT) extension of Asymetrix's ToolBook software, particularly the flexible question templates (widgets) for various forms of computer-based testing. A second essential add-on was the ToolBook Database Connection which provided integral functions for managing external proprietary database files. Whilst this tool added extensive ODBC capabilities to the multimedia authoring tool set, it was designed to operate with Microsoft Paradox data files rather than the company's more widely used Access product. This constraint necessitated familiarising with the Paradox file structure, and methods for attaching Paradox tables to Access database files.

2.8 Formulating conclusions and recommendations

Task 5 of the research programme was to formulate conclusions and recommendations. The overall process and specific methods used are summarised in Fig. 10a, page 54. Provisional outcomes were progressively assembled in handwritten and digital notes as they emerged during the research programme, and used to compile an initial conclusions and recommendations section for periodic updating in the draft thesis (Fig.10a, Steps 1-2). To ensure comprehensive coverage of results from the investigation the draft thesis was then systematically reviewed to identify and index content with direct or indirect concluding significance (Fig. 10a, Step 3). The items identified were then condensed into a substantially smaller number of key points for initial use in preparing a synopsis of the draft thesis to test the overall logic of the research programme and its findings (Fig. 10a, Step 4). Key points were then restructured, using purpose written Visual Basic processes in proprietary spreadsheet software, as principal concepts and recommendations with cross-references to supporting evidence (Fig. 110a, Step 5). Conclusions and recommendations in Sections

4.1-6 on pages 382-457 were then finalised, including proposals for further research and development, based upon consolidated and cross-referenced information in the worksheet (Fig. 10a, Step 6).

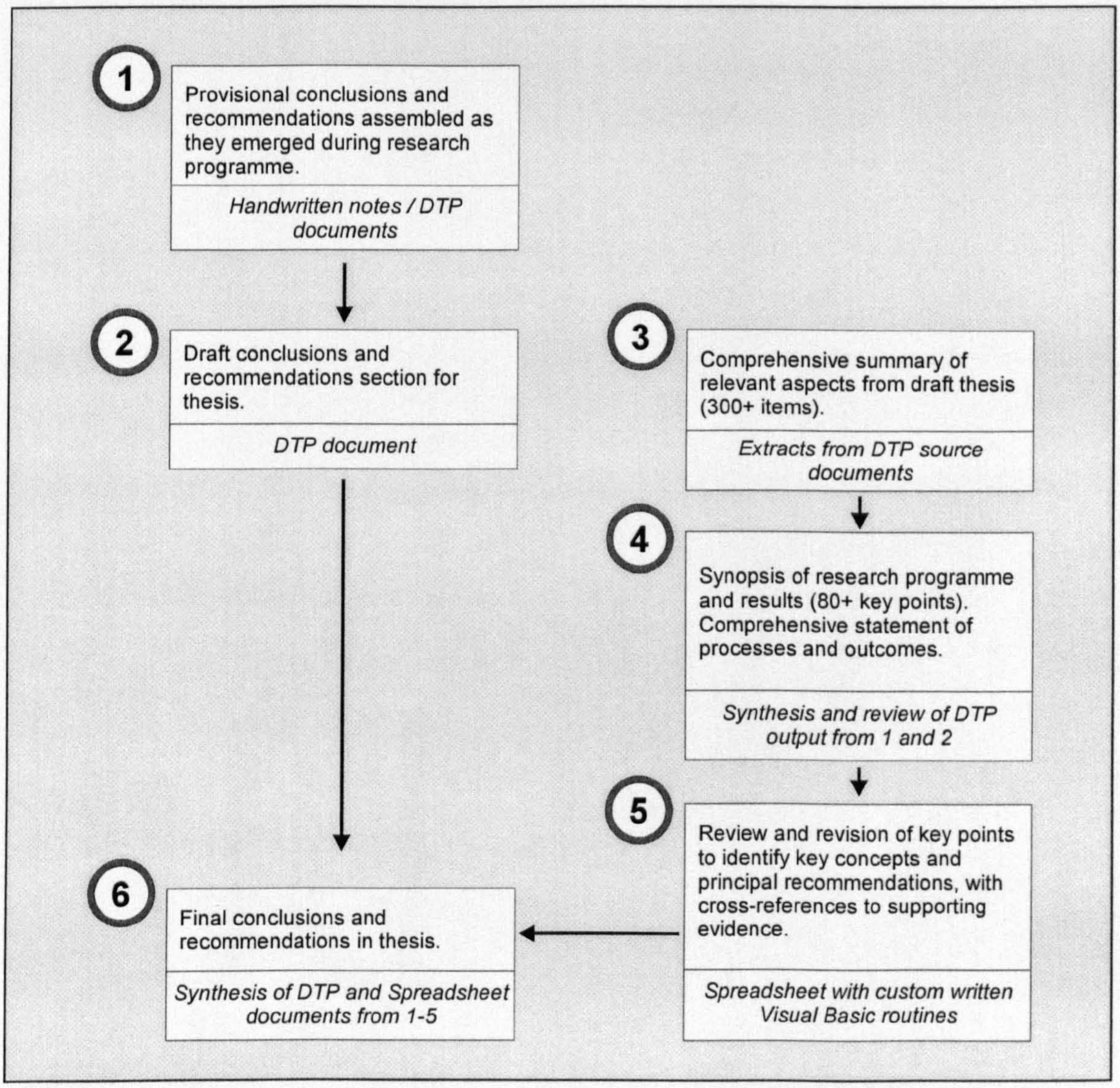
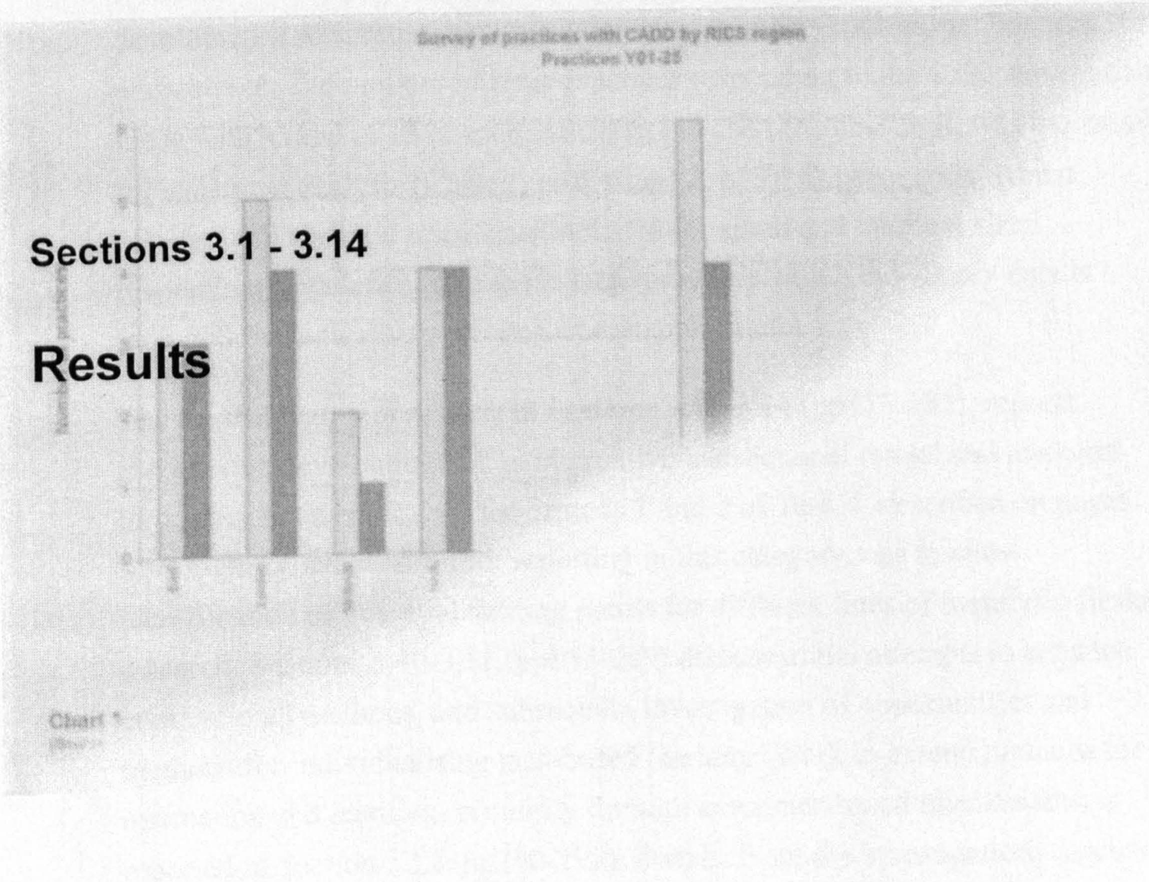


Fig.10a Process and methods for formulating conclusions and recommendations from the investigation



Sections 3.1 - 3.14

Results

3.1. Introduction to results

Results from the research programme are reported in three broad categories of which the first, in Sections 3.2-3.5 (pp58-75), considers the performance of CAD in building surveying practice. Analysis begins with the context and rationale of the survey sample for using CAD, then considers the benefits, problems and requirements reported by respondents.

The second category of results, in Sections 3.6-3.9.2 (pp76-152), considers training for CAD in the context of other related needs. Discussion begins on pages 76-78 of Section 3.6 with an appropriate framework for analysis based upon Romiszowski (1984). Sections 3.7-3.8 (pp78-117) analyse the characteristics and implications of deficient appraisal, start-up, management and development strategies for CAD in the sample. Section 3.9 (pp118-152) identifies human performance deficiencies and priorities of practices for staff development with reference to existing training interventions and the need for alternatives. The number of large practices responding to the 1995 survey, that is those with a total of 15 or more professional and technical staff, was too small for statistical analysis (Chart 1, p58, Chart 2, p59). Consequently, whilst comparative numeric results are included for small and medium sized respondents, evidence from those large practices which did supply data is included for indicative purposes where appropriate.

The third category of results, in Sections 3.10-3.14 (pp153-381), reports progressive development of an alternative instructional model and methods through concurrent R & D for Strands 1 and 2 of Task 4, described on pages 39-53. One consideration for reporting in this category was to allow identification of potential starting points for different lines of inquiry in further research. Sections 3.10-3.11 (pp153-209) discuss initial attempts to enhance conventional methods, and subsequent investigation of opportunities and methods for individualising task-based learning. Work to extend methods for instruction and learning, primarily through computer-based mechanisms, is reported in Section 3.12 (pp210-292). Results from the investigations discussed in Sections 3.10-3.12 required exploration of opportunities for automating training needs analysis, planning and design, which is reported in Section 3.13 (pp293-331). Synthesis of outcomes from exploring alternative instructional models and methods across the research programme is presented in Section 3.14 (pp332-381).

As described on page 23, work undertaken in Tasks 1-4 of the research programme proceeded concurrently for substantial periods. Results were consequently often achieved through nonlinear progression. For clarity, however, the overall structure of reporting in Sections 3.2 - 3.14 retains the logical sequence of Tasks 1-4 (Fig. 1, p22), and various caveats necessarily apply for their interpretation. When considering the discussion which follows it should be appreciated that work reported in Sections 3.10-3.11 and part of 3.12 to identify improved methods for training in R & D Phases 1, 2 and part of 3, predates availability of results from the 1995 survey which are mainly considered beforehand in Sections 3.2-3.9.2 (pp58-152). Moreover, work reported in Sections 3.10-3.11 was undertaken prior to location and assimilation of various significant sources of instructional theory later in the research programme. Sections 3.10 and 3.11 do, however, report data and observations on the characteristic requirements and uses of CAD in building surveying practices resulting from preparatory work with Romiszowski's (1984) paradigm for the survey of practices, and sources other than the survey responses themselves. Where appropriate, Sections 3.10-3.12 (pp153-292) also make reference to results from the 1995 survey as explicit retrospective considerations.

Sections 3.2 - 3.5

Performance of CAD in Building Surveying Practice

3.2. Survey sample and response rate

Survey sample

The survey sample for practices with CAD at 1993, (referred to subsequently as practices Y01-25), included building surveyors from eight of the ten RICS regions applicable at 1995. Geographic distribution of the sample is shown in Chart 1, and a summary of respondents is included in Appendix 2.3.

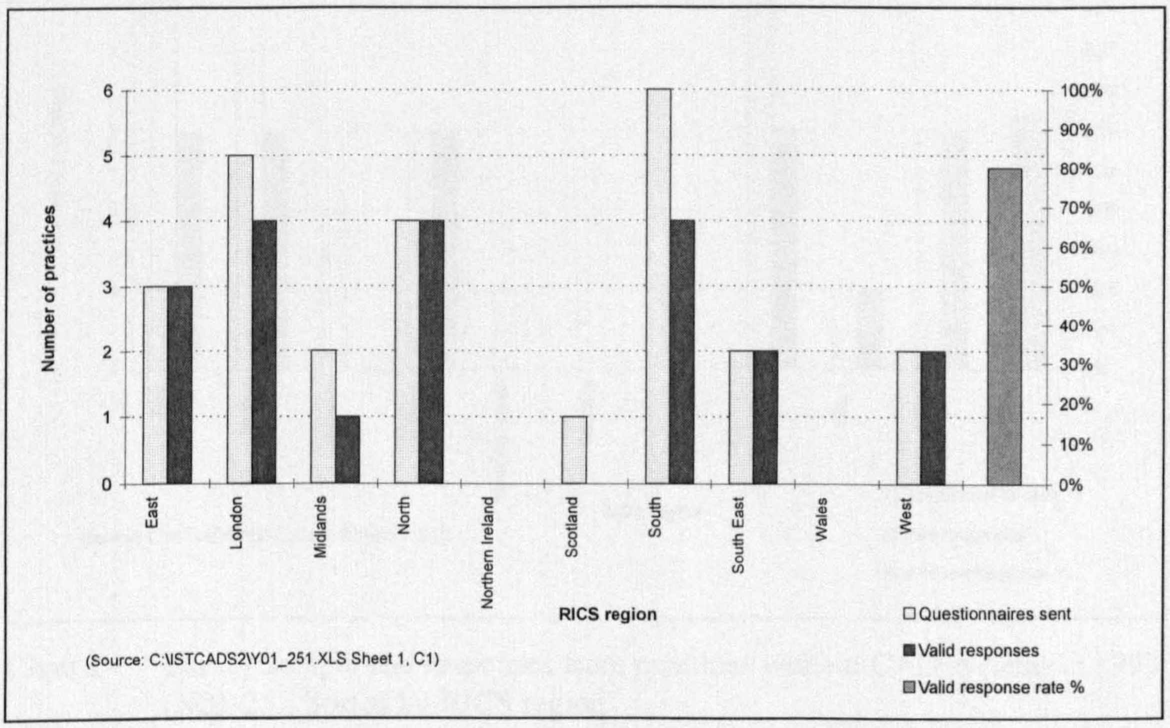


Chart 1 Survey sample and responses from practices with CAD systems at 1993 (Y01-25). Sorted by RICS region

Response rate

Since no response was received from the only Scottish practice in the sample the responding population excluded practices in three of the RICS regions: Scotland, Northern Ireland and Wales. The valid response rate of 80% from this section of the survey population was high for a postal survey and improved substantially upon the 45.4% rate achieved for the original RICS questionnaire in 1993. Although the sample had already demonstrated a willingness to supply information to the Building Surveying Division, responsiveness to the follow-up CAD-specific questionnaire indicated widespread support in the profession for research to improve training methods for CAD. Comparable data for practices in the survey sample which did not have CAD systems at 1993, (referred to subsequently as practices N01-25), are shown in Chart 2, page 59. 64% of this section of the survey population returned a valid questionnaire, giving an overall response rate to the 1995 survey of 72%. This compared with a 48% valid response rate to Richardson's (1994) survey of computerisation in building surveying.

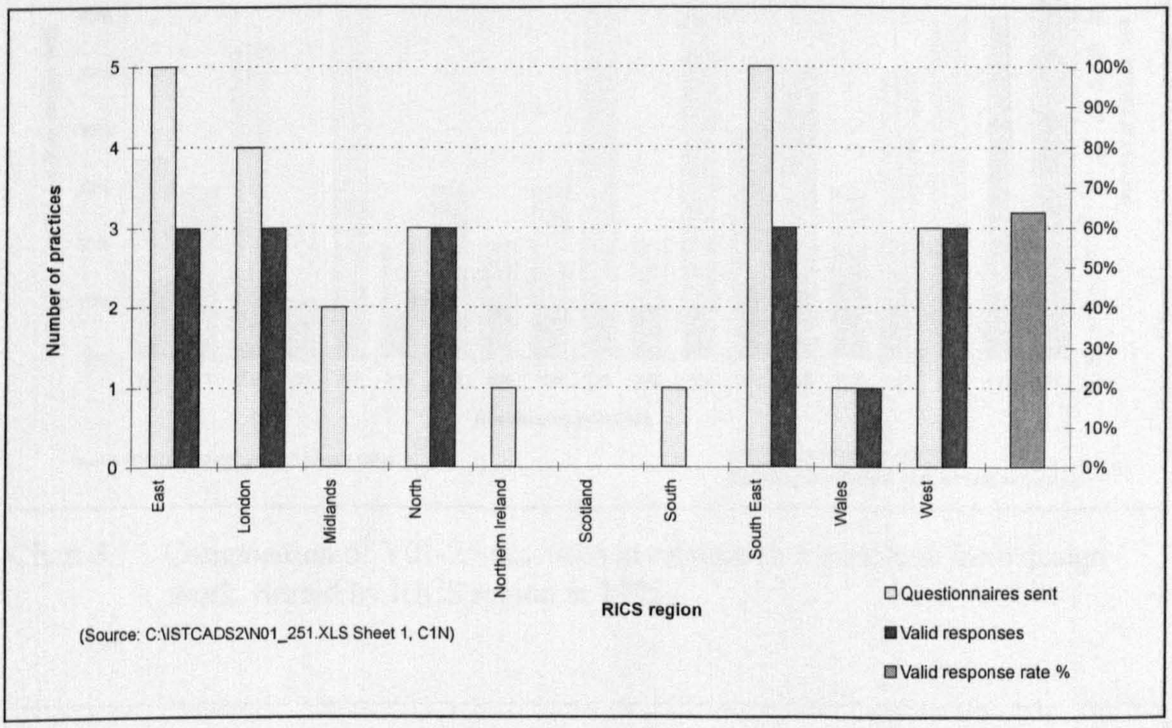


Chart 2 Survey sample and responses from practices without CAD systems at 1993 (N01-25). Sorted by RICS region

3.3. Context and rationale for using CAD

Wide variations were found in the staffing profile of building surveying offices using CAD, as shown in Chart 3, page 60. The smallest offices (Y10, Y23, Y21) were staffed by a single building surveyor, whilst the largest office in the sample (Y11) employed 25.

3.3.1. Characteristics of workload

Practices with CAD at 1993 (Y01-25)

The size and structure of a practice, in conjunction with the scale of design work undertaken, provides the major context for actual and potential CAD applications and associated training requirements. The exception to this general guide occurs where practices use the technology to supply land surveys, measured building surveys, or vectorised hard copy as discrete jobs to clients without further involvement in a scheme.

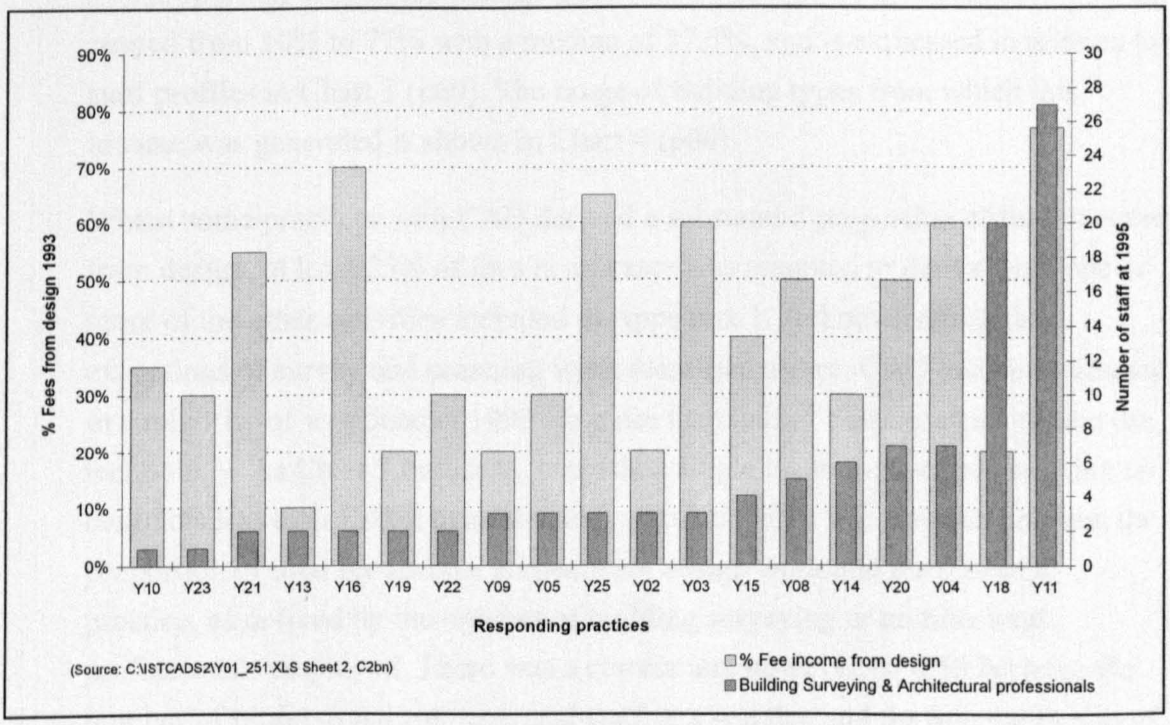


Chart 3 Composition of Y01-25 practices in relation to fee income from design work. Sorted by RICS region at 1995

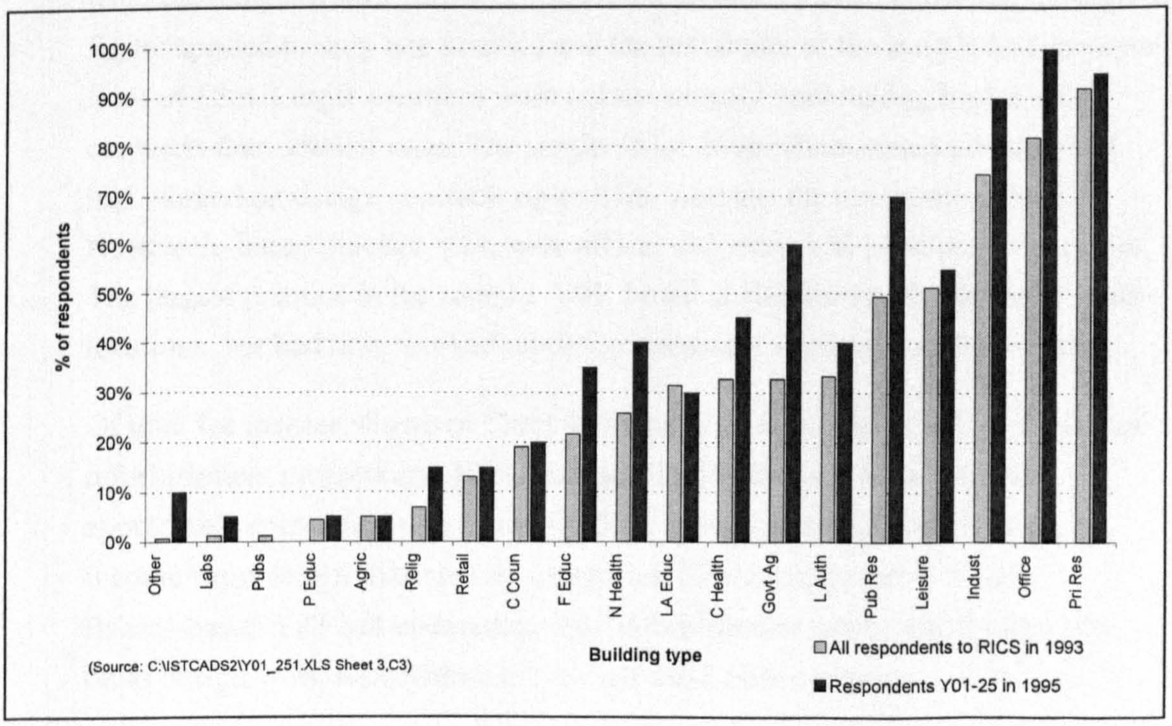


Chart 4 Range of design work undertaken by practices with CAD (Y01-25) at 1993

The proportion of total fee income generated by design work in practices Y01-25 ranged from 10% to 77% with a median of 37.5%, and is expressed in relation to staff profiles in Chart 3 (p60). The range of building types from which this income was generated is shown in Chart 4 (p60).

Whilst some practices with CAD derived a substantial proportion of their income from design, at least 23% of fees in all cases was assumed to derive from one or more of the other activities included in Appendix 1. Acknowledging the exceptions of survey and scanning work identified above, CAD had been a factor in a minority of workload at 1993 for more than half of those practices using the technology. As Chart 3 indicates, other than single location practices working on contracts less than £500k in total value, no relationship was obvious between the proportion of total fee income earned from design work and the size of a practice, as defined by the number of building surveying or architectural professionals employed. There was a correlation, however, of 0.58 between the number of professional and technical staff in a practice and the maximum size of design contract undertaken.

Maximum contract values for practices Y01-25 at 1993, shown in Chart 4a on page 62, ranged from £50k to £30m, with a median of £1m. However, the highest figure applied to only one practice and the remainder of the sample had an upper limit of £5m. Larger practices were not necessarily undertaking higher value contracts than smaller ones. The single office Beckenham-based practice Y04 had worked on design contracts up to £5m, whereas the maximum value for Newcastle-based practice Y14, with offices at 5 other UK locations, was £1.5m. The largest practice in the sample, Y06, based at Hereford with staff at 13 other locations, but had only worked on design contracts worth up to £1m in value.

Of total fee income shown in Chart 4b on page 62 a median of 26.5% was from refurbishment projects and 10% from new build schemes. However, no appreciable correlation was found for the CAD-using sample between fee income from design in these two categories. Newcastle-based Y14 and Bristol-based Y23 had undertaken only refurbishment work, whilst more new build design work was evident in the East and London regions.

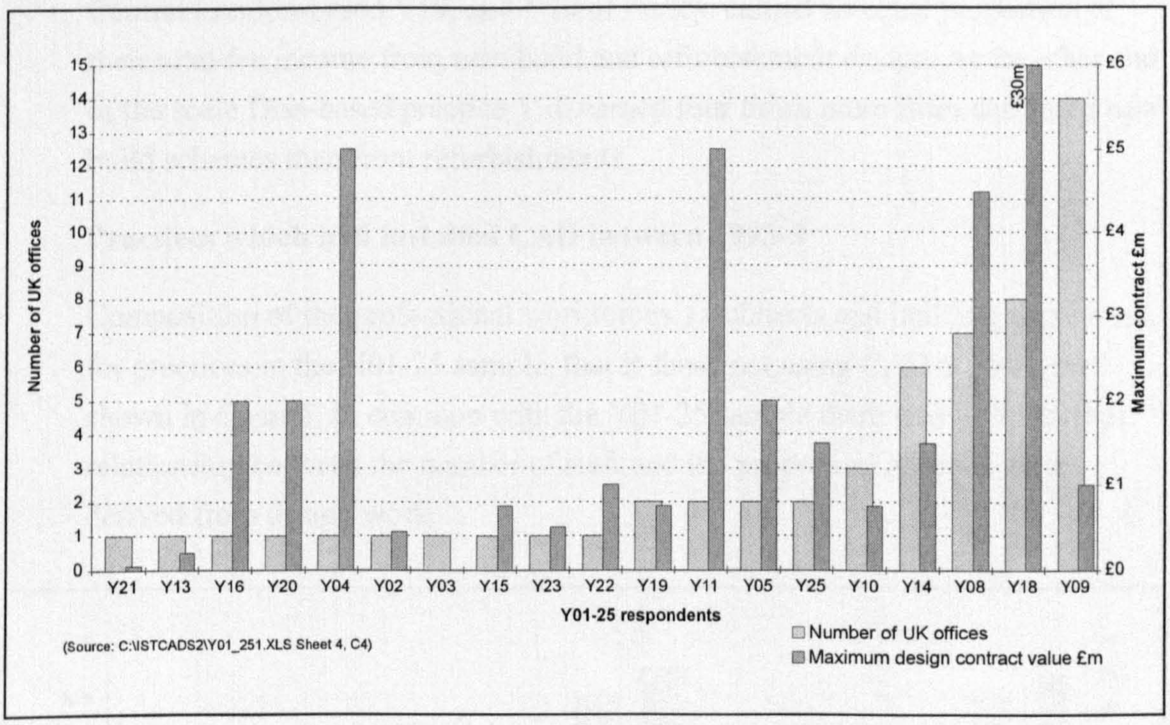


Chart 4a Maximum value of design contracts for practices with CAD (Y01-25) at 1993

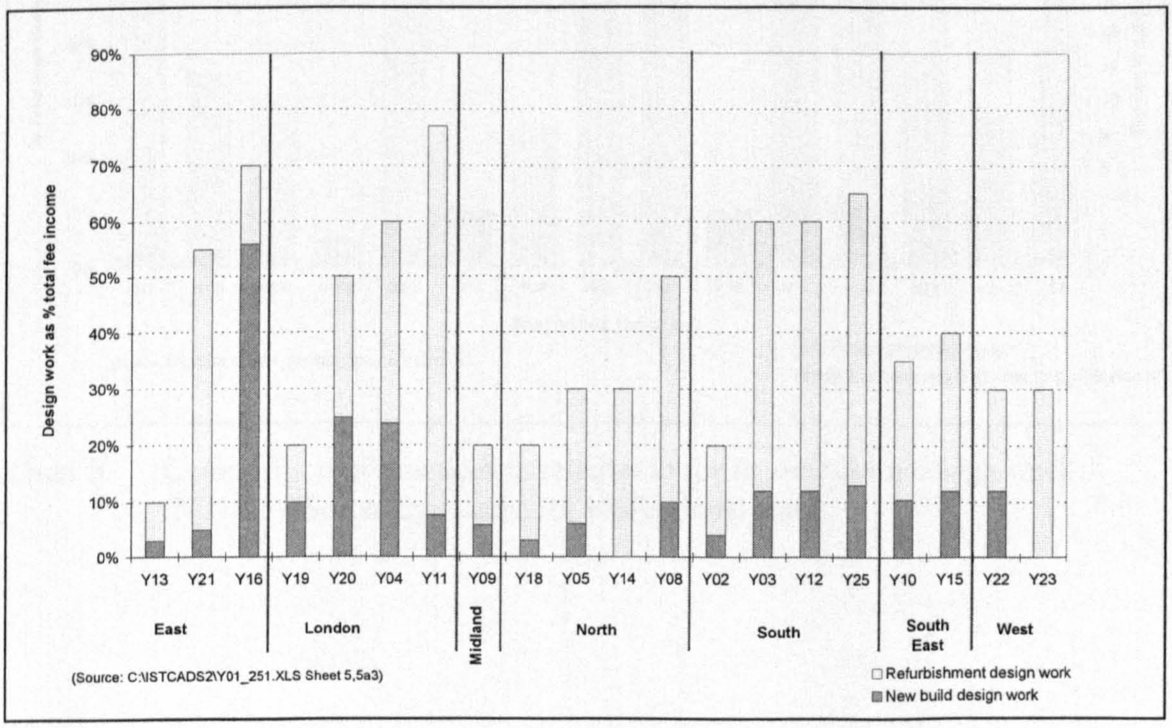


Chart 4b Fee income from new build and refurbishment design for practices with CAD (Y01-25) at 1993

Central London-based Y19, and Y20 of Purley, earned an equal proportion of their total fee income from new build and refurbishment design. At the other end of the scale Diss-based practice Y16 earned four times more from designing new build schemes than from refurbishments.

Practices which had installed CAD between 1993-5

Composition of the professional workforces, (architects and building surveyors), for practices in the N01-25 sample, that is those not using CAD at 1993, are shown in Chart 5. In common with the Y01-25 sample there was little obvious relationship between the number of staff and the proportion of fee income derived from design work.

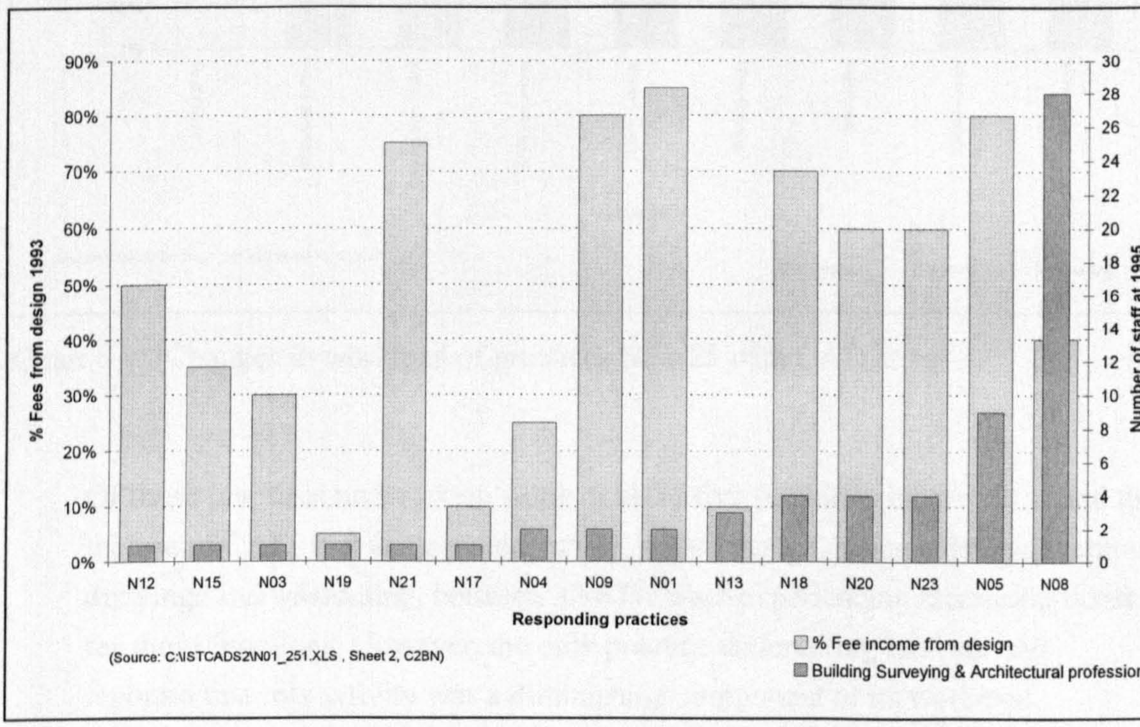


Chart 5 Composition of practices in relation to fee income from design work (N01-25). Sorted by number of professional staff.

Of the N01-25 sample 37.5% had installed CAD since 1993. Within this group more recently using the technology, only half of the returned questionnaires indicated trends in workload, but tentative comparisons are shown in Chart 6.

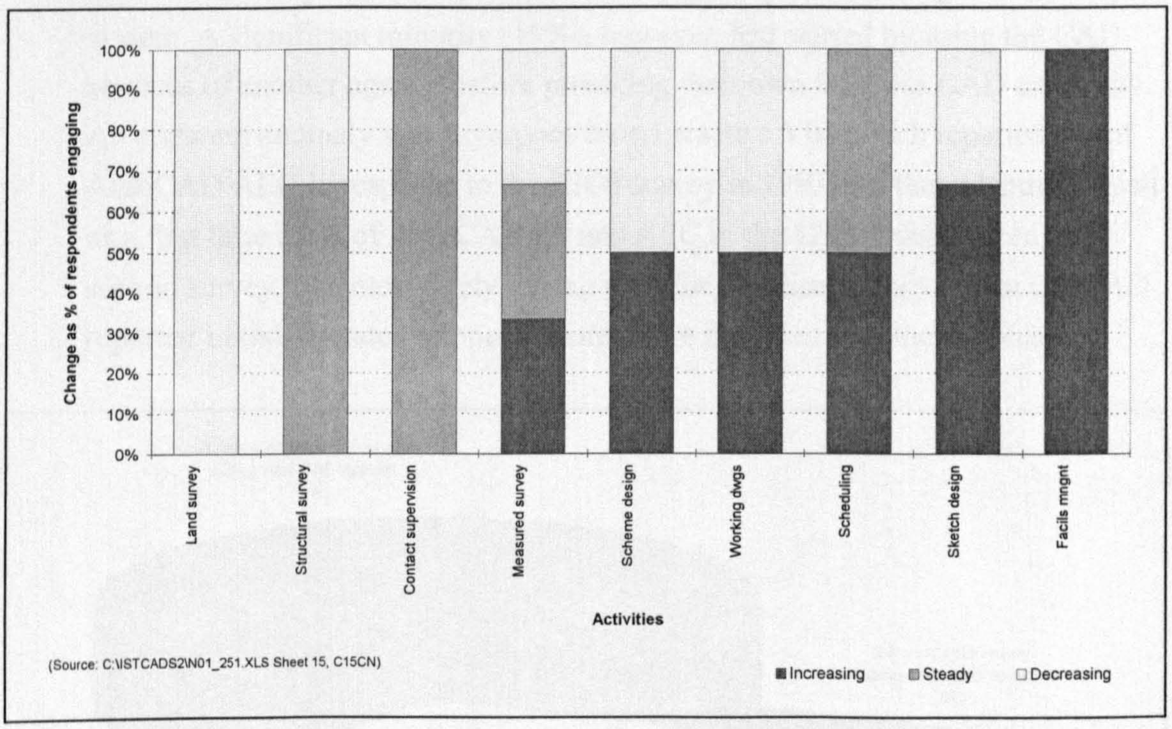
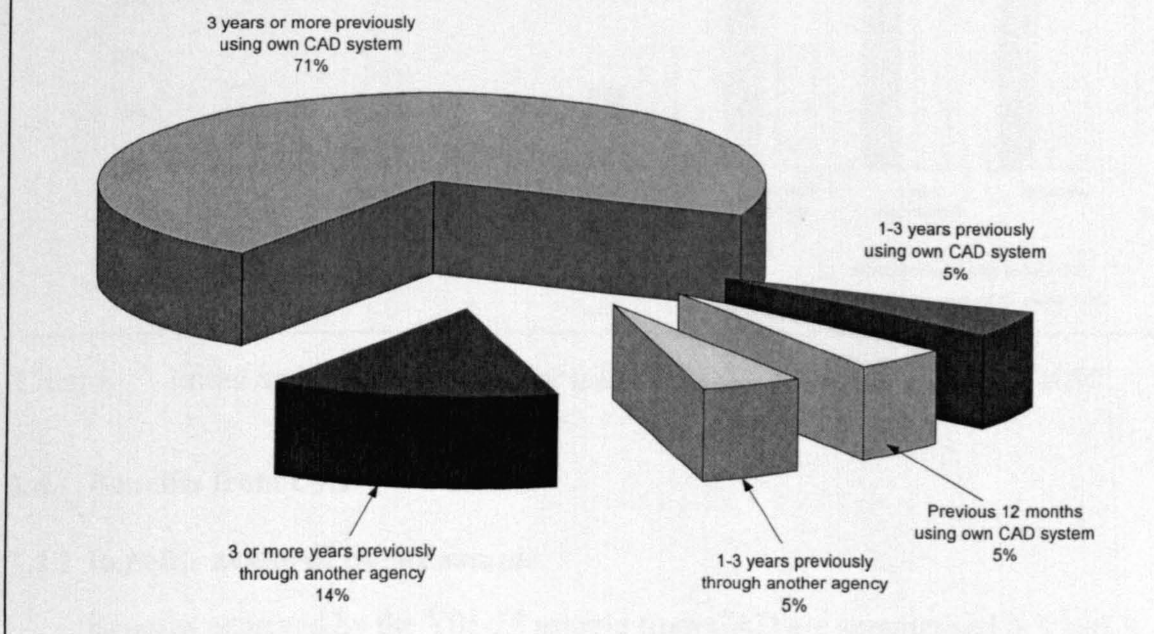


Chart 6 Changes in workload of practices N01-25 with CAD at 1995

Of those practices undertaking some or all of five functions inherently suited to the use of CAD, that is measured survey, sketch design, scheme design, working drawings and scheduling, between 33-67% were experiencing increasing demand for those functions. However, the only practice undertaking land surveys reported that this activity was a diminishing component of its workload. Additionally, between 33-50% of respondents undertaking measured survey, sketch design, scheme design or working drawings reported a reduction in that part of their workload. Facilities management was not a significant undertaking for any of the N01-25 practices still without CAD at 1995. By comparison half of the N01-25 CAD-using group were providing such services, and for the practice which reported a trend this component was increasing. Structural survey and contract supervision were a static component of workload for at least 67% of the CAD-using group in the N01-25 sample.

3.3.2. Initial use of CAD

The chronology for initial use of CAD by the Y01-25 sample is summarised in Chart 7. 85% of responding practices had three or more years experience of CAD at 1995. The majority (81%) had started using CAD by installing their own system. A significant minority (19%), however, had started by using the CAD services of another agency before providing their own in-house CAD capability. An apparent anomaly was Liverpool-based practice Y08 which reported use of AutoCAD AEC in response to the RICS survey in 1993, but then identified itself as a first time users of AutoCAD LT and AEC in the 12 months prior to the second survey. The most likely explanation for this discrepancy is that use CAD reported initially related to one or more of the practices six other offices.



(Source: C:\ISTCADS2\Y01_251.XLS Sheet 9, C9)

Chart 7 Initial use of CAD by practices Y01-25

The rank order of priorities for Y01-25 practices using CAD is summarised in Chart 8, page 66. The underlying data are confined to respondents which specified both their initial and current reasons for using the technology, and each category combines first and second priority rankings. Regarding original priorities, the sample had primarily wanted to improve the efficiency of the practice (86% of respondents), and placed second priority on responding to client requirements for CAD-based services (57%). The sample's third ranking priority was to provide additional services to clients (36%). Requirements for supplying

CAD data ranked fourth (14%), and responding to the requirements of staff in the practice was placed fifth in priority (7%). None of the respondents initially justified installation of their system in terms of marketing the practice, or by needing to use CAD data.

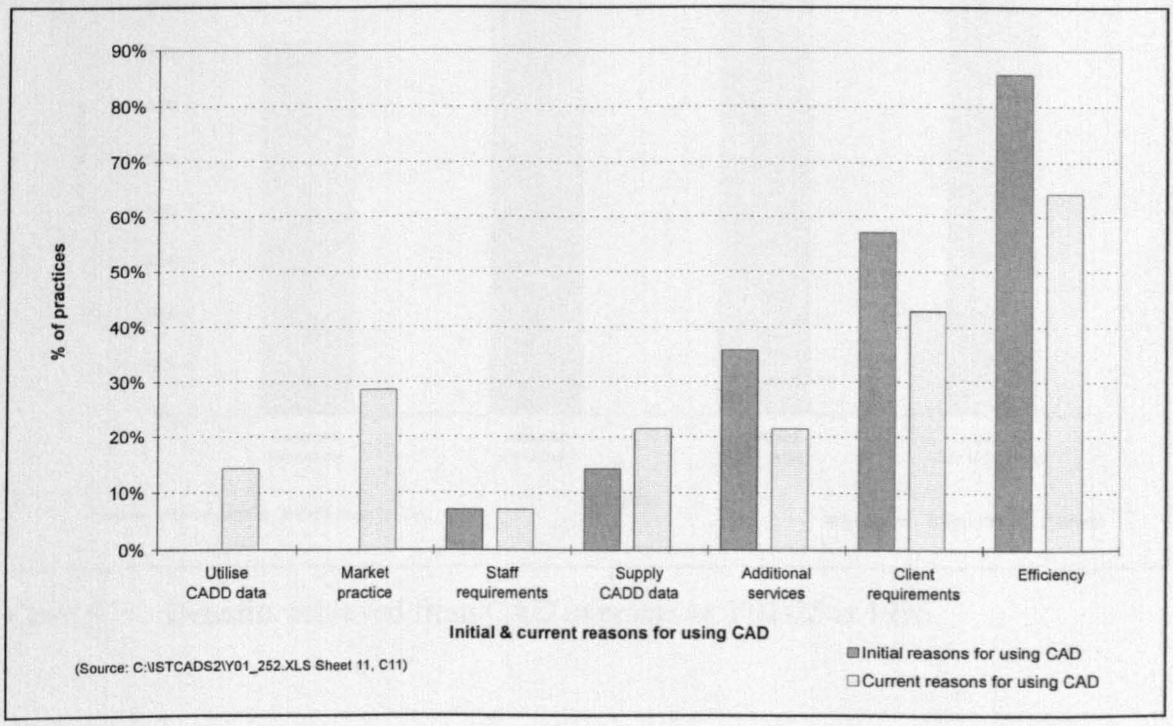


Chart 8 Initial and current reasons for using CAD by practices Y01-25 at 1995.

3.4. Benefits from CAD

3.4.1 Benefits achieved by the sample

Benefits achieved by the Y01-25 sample from CAD are summarised in Chart 9 (p67). In terms of benefits achieved at any interval 100% of the sample had experienced improved productivity, and 94% had benefitted from increased quality of output. A similar proportion had found improved job satisfaction, with additional fee income experienced by 72%. However, a substantial proportion of the benefits indicated in Chart 9 were achieved only irregularly. Corresponding figures for practices achieving the same benefits regularly were as follows:

Increased quality of output	67%
Improved job satisfaction	67%
Improved productivity	44%

Additional fee income 11%

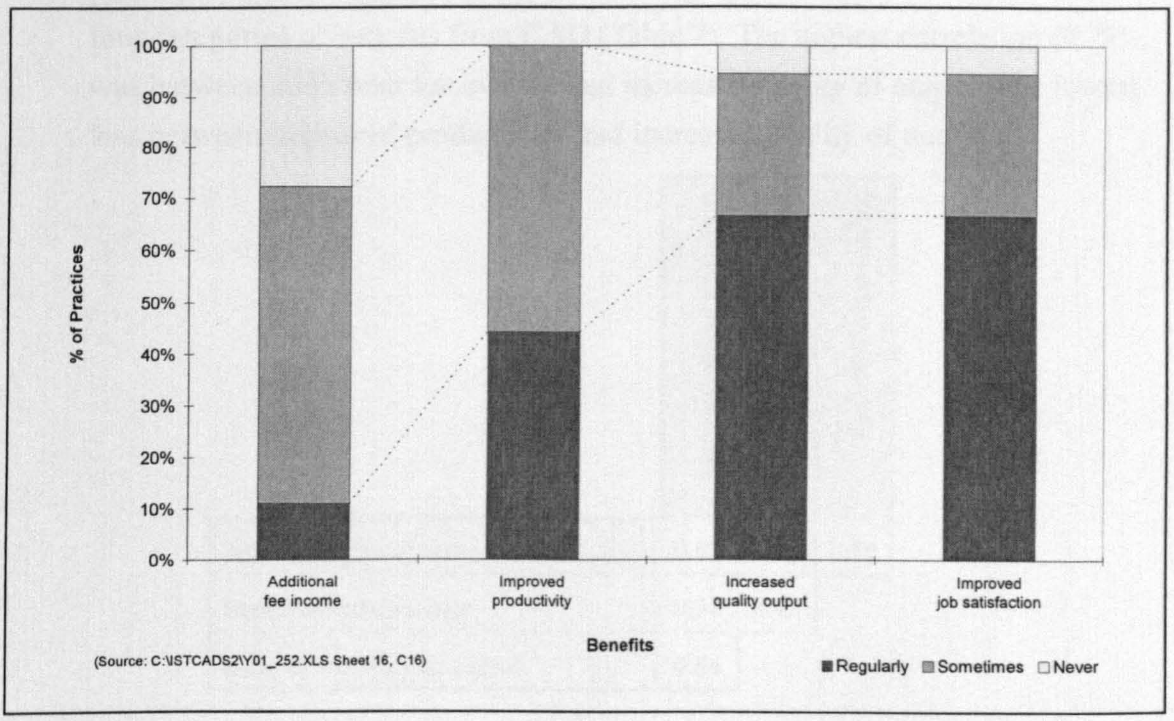


Chart 9 Benefits achieved from CAD in practices Y01-25 at 1995

Users were, therefore, able to sustain the benefits of job satisfaction and improved quality of output more successfully than was achievable for productivity gains.

No significant correlation was found between the total number of professional and technical staff, (including all disciplines and referred to simply as "staff" in the following pages) and the overall index of benefits from CAD[1] in the Y01-25 sample of practices. Only one of the large practices was regularly achieving increased quality of output from their use of CAD, whereas 83% of small, and 60% of medium-sized practices were doing so at the time of the survey. However, both large practices experienced regular improvements in productivity and job satisfaction from use of CAD compared to 30% and 60% respectively of medium sized practices, and 44% and 67% respectively of the whole sample.

1 See page 35 for description of calculation of overall index of benefits from CAD.

3.4.2 Correlation of benefits

Small practices had positive correlations ranging from 0.45 to 0.78 between the four categories of benefits from CAD (Table 7). The highest correlation (0.78) was between additional fee income and increased quality of output. The lowest was between improved productivity and increased quality of output.

	Improved job satisfaction	Increased quality of output	Improved productivity
Additional fee income	0.62	0.78	0.58
Improved productivity	0.71	0.45	
Increased quality of output	0.64		

Table 7 Correlation of benefits for small practices in the Y01-25 sample

Medium sized practices had lower ranging correlations between benefits from CAD of between 0.34 to 0.59 (Table 8). Of these the highest was between additional fee income and improved productivity, whilst the lowest was between increased quality of output and improved job satisfaction.

	Improved job satisfaction	Increased quality of output	Improved productivity
Additional fee income	0.5	0.5	0.59
Improved productivity	0.49	0.49	
Increased quality of output	0.34		

Table 8 Correlation of benefits for medium sized practices in the Y01-25 sample

Insufficient data were returned from large practices in the Y01-25 sample to allow meaningful correlation of benefits from their use of CAD.

3.5. CAD problems and requirements

3.5.1. Problems experienced and solution rates

The incidence of problems experienced by Y01-25 practices as a whole with CAD ranged from a low of 37%, for system maintenance, to the most prevalent at 72% for training of staff to use CAD software systems, and is summarised in Chart 10.

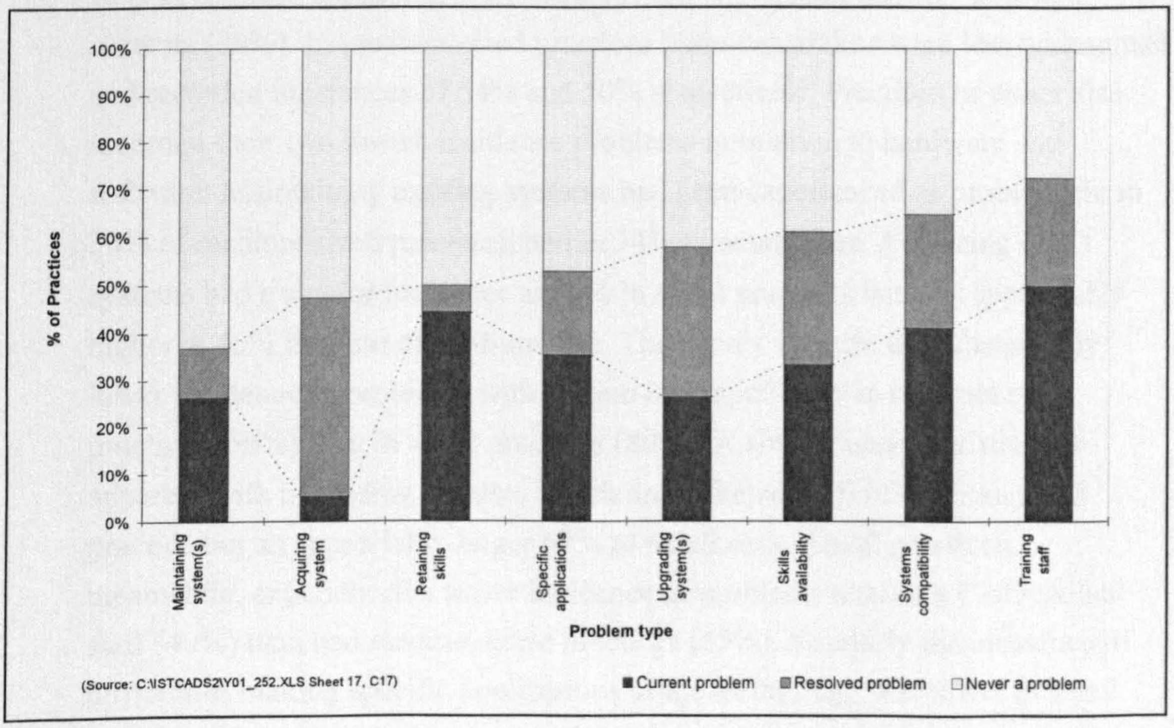


Chart 10 Comparative incidence of problems with CAD in practices Y01-25

Three other problem types were experienced by around one in two of practices, namely system acquisition (47%), retaining CAD-skilled staff (50%), and making specific applications of installed resources (53%). However, the concomitant should also be recognised that, by definition, a similar proportion of practices had been free of problems with these aspects. Three further categories of problem had an appreciably higher incidence, namely difficulties upgrading installed systems (58%), with incompatibilities of hardware and software (65%), or with availability of CAD-skilled staff (61%). Significantly for the research programme the human resource difficulty of training had proved the most prevalent throughout the whole sample, and with an incidence nearly double that for the least widespread problem of system maintenance.

Comparative incidences of problems for medium sized and small practices shown in Charts 11 and 12 on page 71 indicate that human resource constraints were more evident in medium sized practices than in small ones. Difficulties were experienced with skills availability by 70% of medium sized practices, but had only occurred in 34% of small offices. Training staff had been problematic in 80% of medium sized practices but was evident in a much lower proportion (50%) of small practices. For smaller practices the most prevalent difficulties with CAD were upgrading of systems (67%), and incompatibility between systems (80%). In medium sized practices these constraints were less widespread and recorded incidences of 54% and 50% respectively. Practices of either size recorded their two lowest incidence problems in relation to hardware and software. Maintaining existing systems had been experienced as problematic in 36% of medium sized practices, and in 34% of small ones. Acquiring CAD systems had a similar incidence at 33% in small practices but was appreciably higher at 45% in those of medium size. The survey identified a substantially lower incidence of problems with system incompatibility in medium sized practices (50%) than in small practices (80%). A similar characteristic was apparent with upgrading systems which had affected 54% of medium sized practice but an appreciably larger 67% of small ones. Small practices, meanwhile, experienced a lower incidence of problems retaining CAD-skilled staff (40%) than had medium sized practices (55%). Similarly the incidence of difficulties making specific applications of the technology was lower in small practices (40%) than in those of medium size (60%).

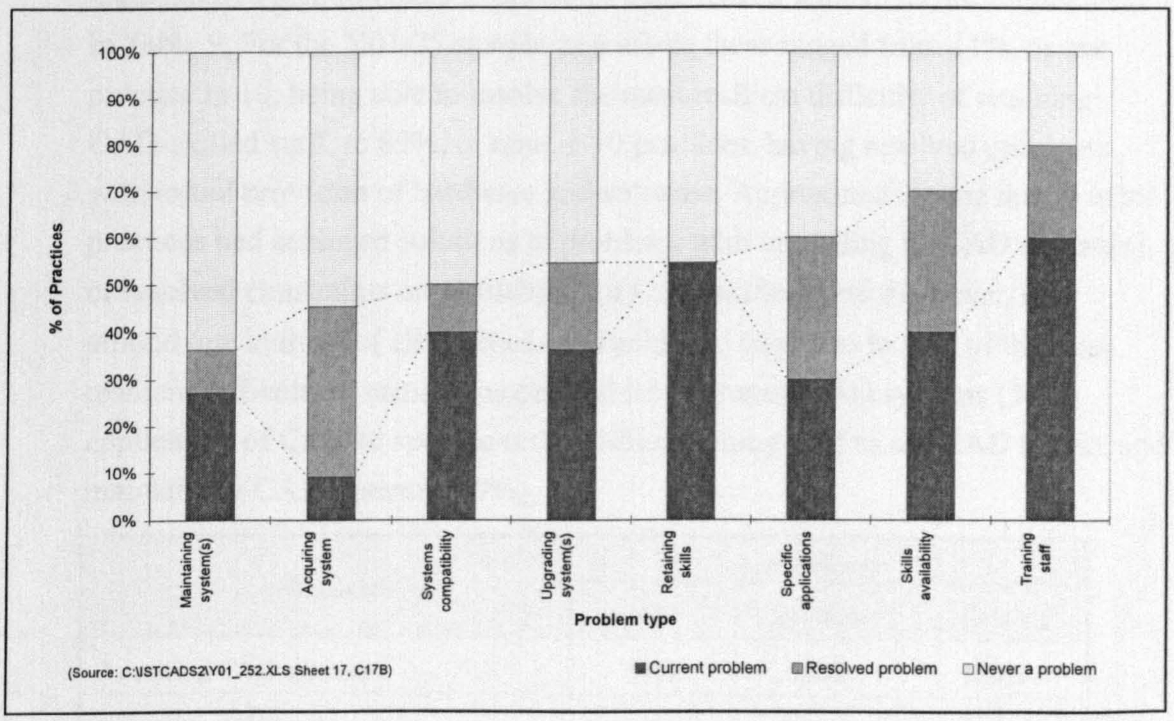


Chart 11 Comparative incidence of problems with CAD in medium sized practices Y01-25

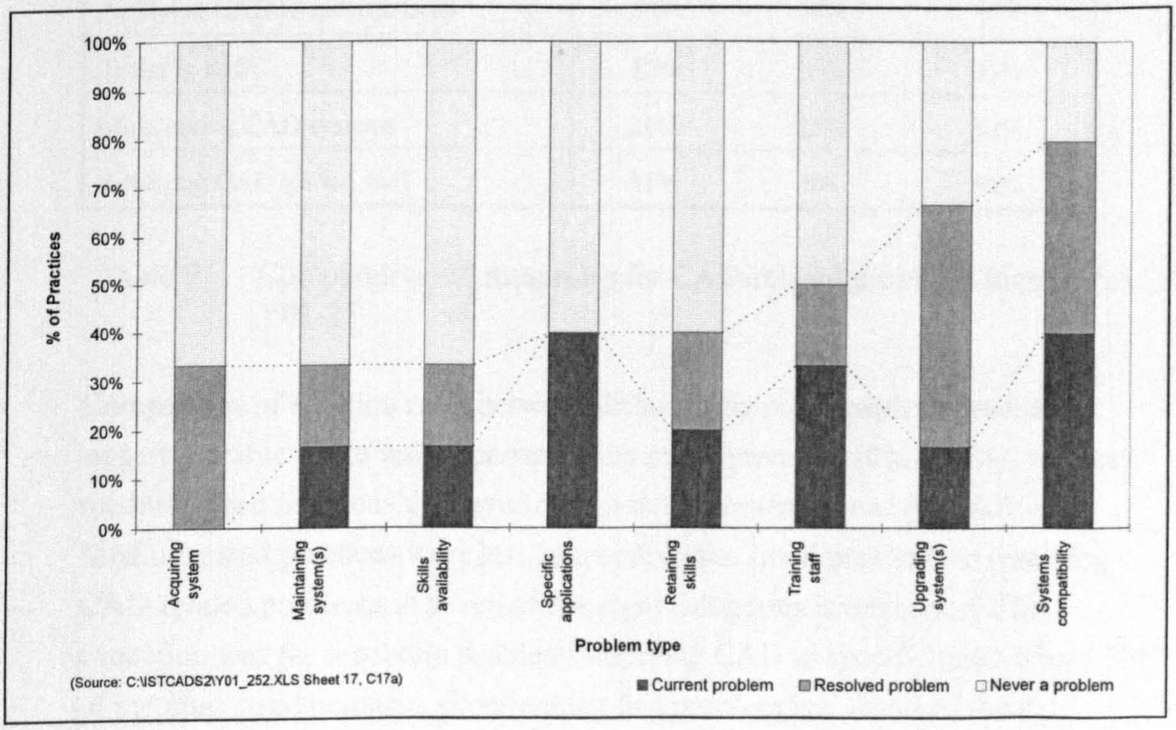


Chart 12 Comparative incidence of problems with CAD in small practices Y01-25

Comparative solution rates to problems experienced with CAD are summarised in Table 9. For the Y01-25 sample as a whole these ranged from 11%, or one practice in 10, being able to resolve the most resilient difficulty of retaining CAD-skilled staff, to 89%, or nine in 10 practices, having resolved problems with initial provision of hardware and software. Approximately one in two of all practices had achieved solutions to problems with upgrading its CAD system(s), or resolved constraints on availability of CAD-skilled staff. However, only around one in three of all practices had achieved solutions to four of the more resilient difficulties, namely, incompatibility between CAD systems (36%), application of CAD to specific tasks (34%), training staff to use CAD (31%), and maintaining CAD systems (29%).

Problem category	Solution rate %		
	All	Medium	Small
Acquiring CAD systems	89%	80%	100%
Upgrading CAD systems	55%	33%	75%
Availability of CAD-skilled staff	45%	43%	50%
Compatibility between CAD systems	36%	20%	50%
Applying CAD to specific tasks	34%	50%	0%
Training staff	31%	25%	33%
Maintaining CAD systems	29%	25%	50%
Retaining CAD skilled staff	11%	0%	50%

Table 9 Comparative solution rates for CAD-related problems in practices Y01-25

Comparison of solution rates between different sizes of practice showed the widest possible range was experienced by small practices (0%-100%), whereas medium sized practices displayed a high but narrower spread (0%-80%). Medium sized practices were less successful than small practices in resolving CAD-related problems in seven of the eight categories investigated. The exception was for resolving problems applying CAD to specific tasks where 50% of medium sized practices experiencing this problem had resolved their difficulties, whilst none of the small practices with similar limitations had been successful. Both groups of practices had generally comparable rates of success resolving two human resource-based constraints. Problematic availability of CAD-skilled staff had been resolved by 43% of medium sized practices and 50%

of small ones experiencing such difficulties. Similarly, training staff to use CAD systems was no longer regarded as a problem by 25% of medium sized practices or 33% of small ones. Small practices had been more successful in resolving problems in three categories, most notably regarding incompatibilities between CAD systems for which 50% had found solutions by comparison to only 20% of medium sized practices. A closely comparable differential was found for upgrading CAD hardware and software where 75% of small practices had successfully resolved their difficulties by comparison to only 33% of medium sized ones. Small practices had also been twice as successful in solving constraints on maintaining CAD systems with a success rate of 50%.

3.5.2. Subsequent priorities for using CAD

Changes from the initial priorities of practices Y01-25 for using CAD to their requirements by 1995 are summarised in Table 10.

Priority		Requirement	% change
Initial	1995		
1	1	To improve efficiency	-26%
2	2	To respond to client requirements	-25%
Unranked	3	To market the practice	-
3	4=	To provide additional services to clients	-42%
4	4=	To supply CAD data	+50%
Unranked	6	To utilise CAD data	-
5	7	To respond to staff requirements	0%

Table 10 Changes by 1995 in the priorities of practices Y01-25 for using CAD

The need to improve efficiency in the practice remained, at 64%, the primary reason for using CAD but was ranked first or second in importance by 22% fewer respondents. Various explanations were possible why these practices no longer ranked efficiency gain amongst their highest priorities. Some may have come to regard use of CAD as primarily a response to client requirements, or considered that an acceptable level of efficiency had already been achieved. Others may simply have stopped seeking efficiency gains for one or more reasons regardless of achievements since installing CAD.

Although at 43% it remained the sample's second most important reason for continuing to use CAD, fewer practices ranked responding to client requirements for CAD-based services as their first or second most significant justification. The 14% of respondents no longer emphasising this requirement may have experienced lower demand from clients for CAD work, or otherwise modified their workload since installing their systems.

The third most important reason for using CAD at 1995 was its actual or anticipated contribution to marketing the practice. 29% of respondents ranked this as their first or second most important justification although none had considered it a primary reason for installing CAD initially. The increase was possibly explained in terms of the need for competitive advantage to secure work during, and subsequent to, the 1992-3 economic recession.

The number of respondents regarding provision of additional services to clients as a main reason for using CAD dropped to 21%, and fourth equal priority, at 1995. This reduction might be explained by a discrepancy between initial perceptions of potential for additional CAD-based services and proven demand for them. Alternatively, practices may have experienced a real reduction in client demand for additional services since installing CAD, or successfully reached the limits of provision for additional service.

There was a 50% growth to fourth equal priority, albeit from a low base of 14%, in the number of practices which considered that their capacity for supplying CAD data was a primary reason for continuing to use the technology. When taken with the 25% reduction in priority for responding to client requirements this substantial rise suggested increasing acceptance of CAD data as the norm, rather than the exceptional requirement of some clients.

The sixth ranking reason for using CAD at 1995 was to utilise digital data (15%). This requirement had not been an initial priority for any respondent and its emergence represented the second largest increase in perceived significance. Further research would be required to establish the extent to which respondents were referring to reuse of in-house data, incorporation of data from manufacturers, or development of CAD files from collaborating practices. Although the relative increase in its significance was substantial, a low ranking priority for continuing use of CAD in order to utilise digital data may have been explained by two factors. Firstly a significant number of schemes may have involved respondents with only land surveys and measured building surveys in their early stages, making them the suppliers of data rather than their recipients. Secondly the design activity of practices may have been relatively self-contained, with projects serviced mainly in-house rather than through collaboration with other practices.

Providing for staff requirements remained the lowest priority rationale for use of CAD, and was unchanged since installation at 7% of respondents. Such a low ranking may have reflected a simplistic perception of CAD by decision-makers as a productivity tool upon which staff preferences had little bearing. It might also have indicated pervasive low interest amongst practitioners in CAD and its implementation. Conversely, the low ranking could have been indicative of suppressed concern with CAD from staff in building surveying offices. These alternative explanations had various implications for perceptions of staff development to use available CAD systems.

3.5.3. Mismatch between requirements and achievements

For CAD-using practices as a whole a substantial mismatch was found between the current rank order of reasons for using CAD at 1995 and benefits received (Chart 8, p66; Chart 9, p67; Table 10, p73). Most obviously, although all respondents were achieving some degree of improved productivity, less than half were doing so regularly, despite a first ranking reason amongst the Y01-25 sample for using CAD to improve efficiency. With a solution rate of only 11%, retaining CAD-skilled staff was the most resilient human resource problem for the whole sample. Amongst medium sized practices 55% were experiencing such difficulties, making it their second most prevalent current constraint, and one which none had been able to resolve. Although problems involving human performance deficiencies had the highest incidence for the overall sample, the interaction of a complex range of factors needed investigating to inform conclusions on appropriate remedial action, and the role of training within it. The results of that analysis are discussed in Sections 3.6 - 3.9, on pages 76-152.

Sections 3.6 - 3.9.2

CAD Training and Other Needs

3.6. Assessing CAD training and other needs

Romiszowski (1984, pp100-8) categorised the causes of problems experienced in organisations as deficiencies in one or more of three categories:

1. Material resources, including environmental conditions.
2. Methods and equipment, including systems of management and supervision.
3. Human performance.

He proposed a further classification of human performance deficiencies in terms of the types of solution to which they might respond:

3.1. Instruction.

3.2. Other training or development actions.

3.3. Non-training solutions.

Distinguishing the relative influence of such deficiencies is, for Romiszowski, a a core function of management[1] and the prerequisite to specifying an appropriate mix of solutions. It follows, in his analysis, that training can provide a primary remedy for some, and only some, of the human performance deficiencies in category three. Moreover, focusing too soon, or too vigorously, on human performance deficiencies in any particular case is likely to limit the potential of proposed solutions and prospects for success. Since training is the primary concern of this investigation, the description "other needs" is used for collective reference to those deficiencies which are not directly responsive to instruction. The potential range of such factors which might interact to reduce the effectiveness of CAD in a practice is thereby acknowledged without implying that they are necessarily of secondary importance. Fig.11 (p77) shows Romiszowski's overall methodology applied to design, drawing and associated processes, for example collation of sources and distribution of output, in building surveying practice. This analytical framework can be used either to review requirements for CAD in manually-based practices, or to assess problems with existing systems in practices already using the technology.

1 See also Harless (1968) on the importance of appropriate analysis.

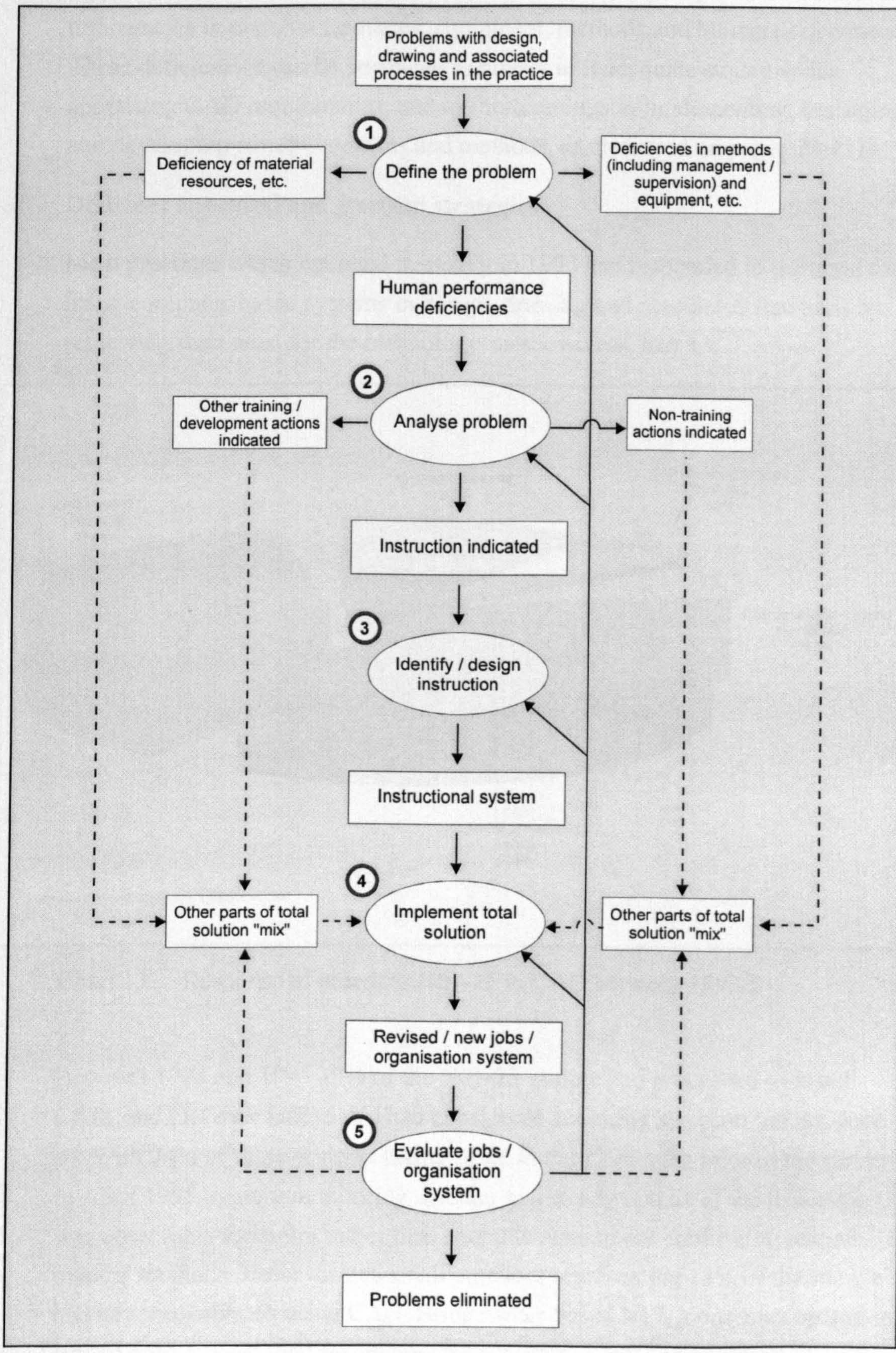


Fig. 11 Analysis of problems with design, drawing and associated processes in a building surveying practice (after Romiszowski, 1984)

Application of this schema to data from the 1995 survey of practices identified deficiencies in material resources, equipment, methods and human performance. These deficiencies can be attributed variously to inadequate strategies for appraising CAD requirements, and to shortcomings in implementing, managing and developing suitable systems and methods, as discussed on pages 78-117.

3.7. Deficient appraisal and start-up strategies

Most practices which operated manually in 1993 had responded to the trend for using computer-based systems in design, drawing and associated functions by reviewing their need for the technology, as shown in Chart 13.

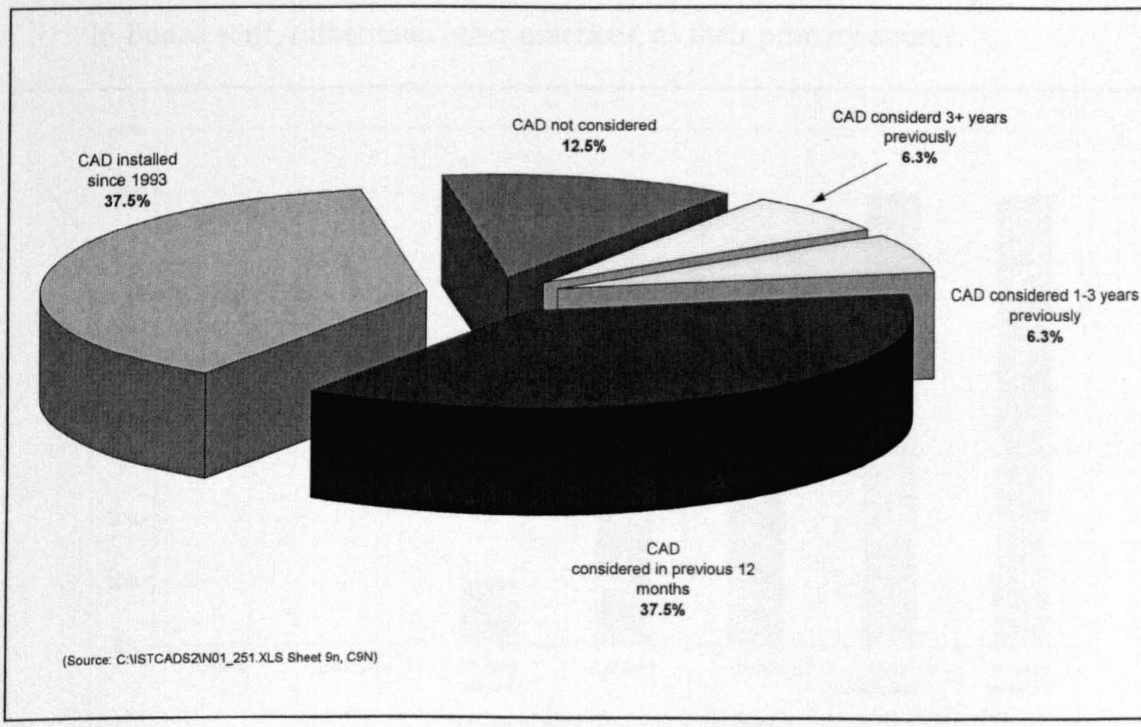


Chart 13 Response of practices N01-25 to CAD between 1993-5

Between 1993 and 1995 38% of the N01-25 sample had proceeded to install CAD, and just over half (51%) had considered acquiring a system but not done so. With 74% of these reviews taking place in the 12 months prior to the survey in April 1995, regular monitoring, leading to a steady uptake of the technology, was observably the norm rather than sporadic assessment confirming retention of manual methods. However two small practices representing 13% of the sample had never considered using CAD. Bridgewater-based N17, a one-man operation, earned only 10% of total fee income from design at 1993 on contracts of up to £50k in total value, and had a 6:4 ratio between new build and refurbishment commissions. Orpington-based practice N03, staffed by one building surveyor and a technician, earned 30% of fees from design work on schemes up to £1m in value. 95% of the practice's design work involved refurbishment. In addition the Evesham-based practice N25 returned the single comment "What is CAD?" on an otherwise empty survey questionnaire, and was assumed not to have considered acquisition either.

The effectiveness of regular monitoring in the sample was, however, potentially compromised by its selection of sources for decision-making. The first or second most significant sources for 70% of all N01-25 respondents were their own staff, and other practices, (Chart 14). Of these, a third more practices regarded in-house staff, rather than other practices, as their primary source.

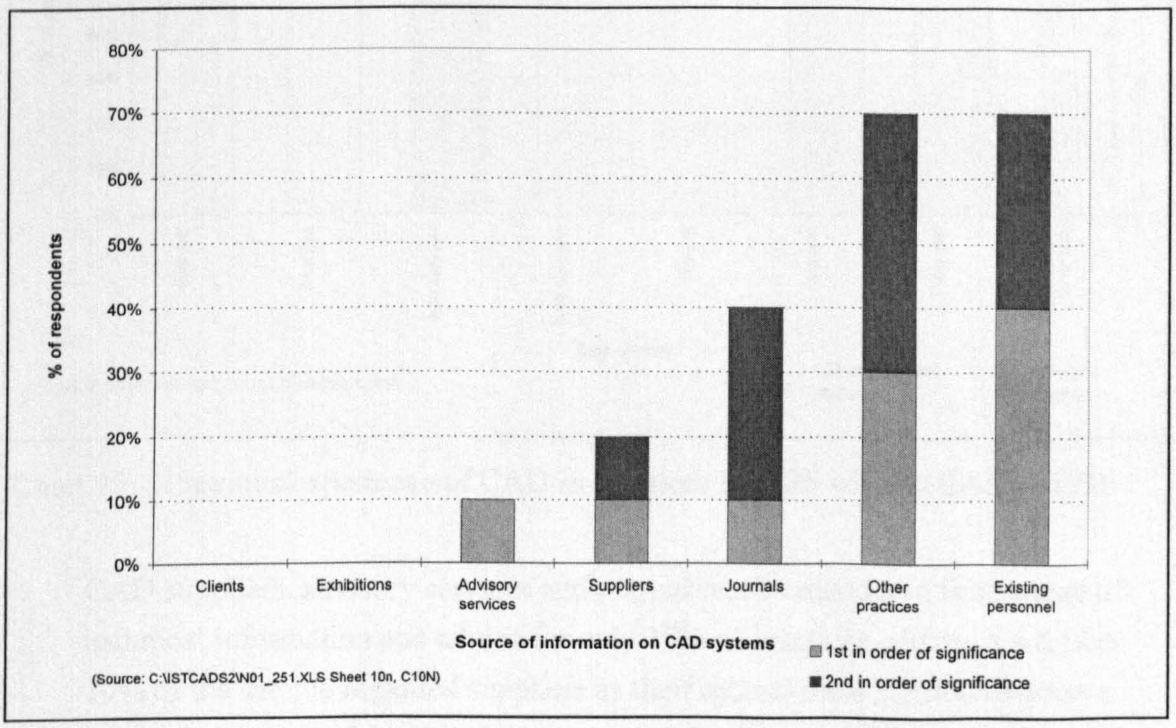


Chart 14 Sources used by practices N01-25 for information on CAD systems

Unfortunately, as shown in Chart 15 (p80), the previous experience of staff was not necessarily conducive to undertaking an informed appraisal. Workforces in these N01-25 practices comprised mainly of building surveying professionals and technicians. Of the professional staff only 20% had some experience of using CAD, whilst the remainder had little or none. With respect to the second primary source, the utility of information and advice from other practices was likely to depend initially upon the extent to which they shared significant characteristics with the enquiring practice. Assuming adequate comparability, the success or otherwise of their own use of CAD was likely to influence the advice given. The substantial problems and under-achievement experienced with CAD by the Y01-25 sample is discussed in Section 3.5 (pp69-75). Responding practices might reasonably be considered representative of those established users of CAD approached for advice by practices considering installation. The implication was for advice on the technology to reflect substantially negative experiences.

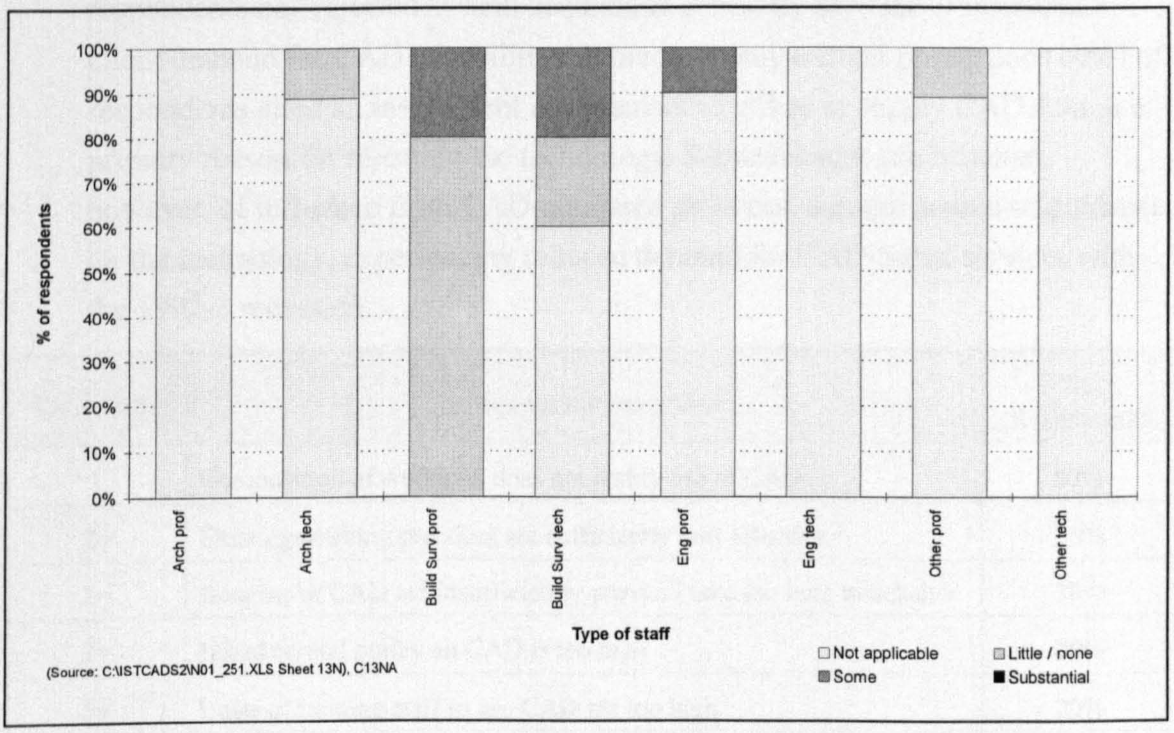


Chart 15 Previous experience of CAD in practices N01-25 without CAD at 1995

CAD suppliers, advisory services and journals each ranked as a first source of technical information and advice for only 10% of practices, although a further 10% of the sample regarded suppliers as their second most significant source. Low engagement of the N01-25 sample with suppliers might have indicated that few practices without the technology had seriously considered system acquisition in their most recent evaluation of CAD. They may also have been dissuaded from consulting more extensively with suppliers through fear of aggressive promotion for products about which they had little knowledge. By contrast 77% of established CAD users in the Y01-25 sample regarded suppliers as their most important source of information when acquiring their current CAD system. Only one in three of the N01-25 practices which had purchased a system identified a similarly significant role for suppliers.

Decision-making on CAD acquisition and start-up strategies was, therefore, questionable in a substantial part of the N01-25 sample. The assessment from 80% of manually-based practices, more than double that for the next ranking reason (Table 11), that CAD was principally rendered inappropriate by their unsuitable workload, may not have survived more informed analysis. Opportunities existed for reaching different conclusions since none of these respondents had rejected system acquisition primarily because of inadequate client demand for CAD capabilities. Moreover, only a small proportion (10%) of respondents cited an insufficient requirement to utilise or supply CAD data as a primary reason for rejecting the technology. Some account can be taken, however, of influence from CAD-equipped practices, a major source of guidance on the technology, experiencing reduced demand for CAD-based services with the 1992-3 recession.

Rank order	Reason for not using CAD	% Respondents
1	Composition of workload does not justify use of CAD	80%
2=	Existing working practices are sufficiently cost effective	30%
2=	Benefits of CAD are insufficiently proven / take too long to achieve	30%
2=	Initial capital outlay on CAD is too high	30%
5=	Costs of training staff to use CAD are too high	20%
5=	Costs of maintaining CAD hardware and software are too high	20%
7	No requirement to utilise or supply data in CAD format	10%
-	Insufficient client demand for CAD capabilities	0%
-	Staff prefer existing working methods	0%

Table 11 Rank order of reasons for not using CAD in practices N01-25 at 1995

Other results also suggest that CAD could have been viable in more offices, given appropriate changes in working practices and the type of projects undertaken. A median of 40% of total CAD resources in the Y01-25 sample was allocated to production of working drawings. Using this application to indicate the potential viability of CAD it was found that production of working drawings had a higher incidence in the N01-25 sample of practices without CAD than those which had installed the technology since 1993. Although this activity was their most changeable component of workload it was also increasing for 22% of manually-based respondents at 1995.

Four aspects of the evidently inadequate appraisal were particularly significant. Firstly, manual methods appeared to have been retained less because CAD was inherently unsuitable, and more to avoid the operational change and potential disruption of implementing the technology. The flexibility which may instead be needed to sustain viable provision for CAD was demonstrated by a corporate building surveying department in Leicester. In this case the principal found alternative sources of work specifically to help occupy, and thereby retain, hardware, software and CAD-skilled staff during a downturn of internal demand for their services during the early 1990s. By contrast, for Y12 at Henley-on-Thames, a decline in demand for core services led to an assessment that CAD was unsustainable and subsequent abandoning of the technology. Secondly, it was likely that because of inadequate appraisal some practices which proceeded to install a system may not have fully considered the resourcing, human performance or organisational changes required to make it successful. This could account for a strongly negative reaction to future use of CAD in practices like Hereford-based practice Y06 which had experienced failed installations:

> "We are an extremely busy professional practice, had we depended on computerisation we may well have been bankrupt."[1]

A third significant aspect, the conclusion that expenditure on CAD would not achieve adequate efficiency gains, may have been accurate given the experience of some Y01-25 practices (Chart 9, p67). However, the potential commercial consequences of continuing without CAD, given trends in its uptake, may not have received adequate consideration. Appraisers might also have been unaware of management action capable of positively affecting the cost-benefit analysis to indicate potentially viable use of CAD in the practice.

A fourth and striking feature of inadequate analysis for CAD in the whole sample was the marginal influence of staff requirements on decision-making. Only 5% of Y01-25 practices identified staff requirements for the technology as a primary reason for installing a system. Despite personnel in 67% of the Y01-25 sample regularly experiencing improved job satisfaction through its use (Chart 9, p68),

1 Letter from Hugo Mason, Partner, Hook Mason Architects and Surveyors, 27th February, 1995.

staff requirements remained the lowest consideration for continuing use of CAD at 1995. Conversely, however, none of the respondents in the N01-25 sample still manually-based at 1995 considered staff preference for existing working methods to be a primary reason for not using CAD. Building surveying practices were evidently consistently indifferent to the preferences of their workforce when making strategic decisions about CAD, with consequent potential for negative attitudes towards software systems, associated training, and overall development of the technology.

Implications for practice

In a context of the growing global importance of digital methods for commercial activity, and the trend for uptake of CAD in building surveying (p79), failure by some practices to give any consideration at all to using the technology appeared a significant omission of management. Practices not using CAD needed instead to periodically and objectively review their organisation and workplaces in relation to available systems, and consider the consequences of implementation for their procedures and human resources. Adequate appraisal of the relative benefits in retaining manual methods of design, drawing and associated functions, or deploying CAD-based alternatives, required various capabilities. Appraisers needed awareness of the potential for digital methods to change the supply and demand for building surveying services, and trends in the transformation process. Techniques for undertaking the analysis indicated in Fig. 11 (p77) were also required. Moreover, appraisers needed to appreciate the conditions required for effective use of CAD, including effective techniques for managing the transition from manual to digital methods. In particular, where an established practice starts up with CAD then its implementation strategy and associated training should accommodate potential anxiety at the impact on high earning components of workload, and frustration at enforced changes in working methods.

Depending upon in-house knowledge and available resources, practices considering use of CAD may require staff development for appraising their options, and initiating a strategy to acquire and implement suitable system(s). Although instruction is likely, therefore, to form a significant component of the solution mix for deficient appraisal and start-up strategies, success will be constrained without appropriate interaction and communication between interested parties. In particular the 1995 survey suggests that practices should be more willing and able to place a higher priority on staff requirements, preferences and suggestions in preparation for more inclusive management and development of the technology. Practices should also seek expert advice, as necessary, to supplement in-house expertise, or to compensate for its absence. Such advice should involve effective interaction with suppliers of CAD hardware and software.

Where, after objective analysis in a practice with commercially significant design, drawing and associated functions, CAD is not implemented then management should consider the need to address any underlying structural problems relative to its competitors. They should also give appropriate consideration to the commercial implications of under-investment in appropriate new technology and associated staff development.

3.8. Deficient management and development strategies

The experiences of practices after installing CAD suggested that most had yet to achieve either satisfactory provision of hardware and software, effective methods for using their existing CAD resources, or strategies for gaining more commercial benefit from the technology. Analysis of data from the 1995 survey identified four characteristic problems which are discussed on pages 84-117:

- Multiplicity of CAD systems.
- Underperforming hardware and software.
- Limited availability of hardware, software and staff.
- Inadequately collaborative working practices.

3.8.1. Multiplicity of CAD software systems

Overall, and including N01-25 practices with the technology, the sample was using 12 different proprietary CAD software systems (Charts 17 and 18, p85). An apparently inaccurate overall total in Chart 17 occurred because 32% of respondents had two different CAD software systems at 1995, and 16% of practices had three, as shown in Chart 19 (p86). 38% of the combined sample were using AutoCAD, 17% AutoCAD AEC and 10% used AutoCAD LT. The evident range of installed CAD software in the Y01-25 sample partly reflected the diverse resourcing capabilities of building surveying practices as a whole in response to a wide variety of available products.

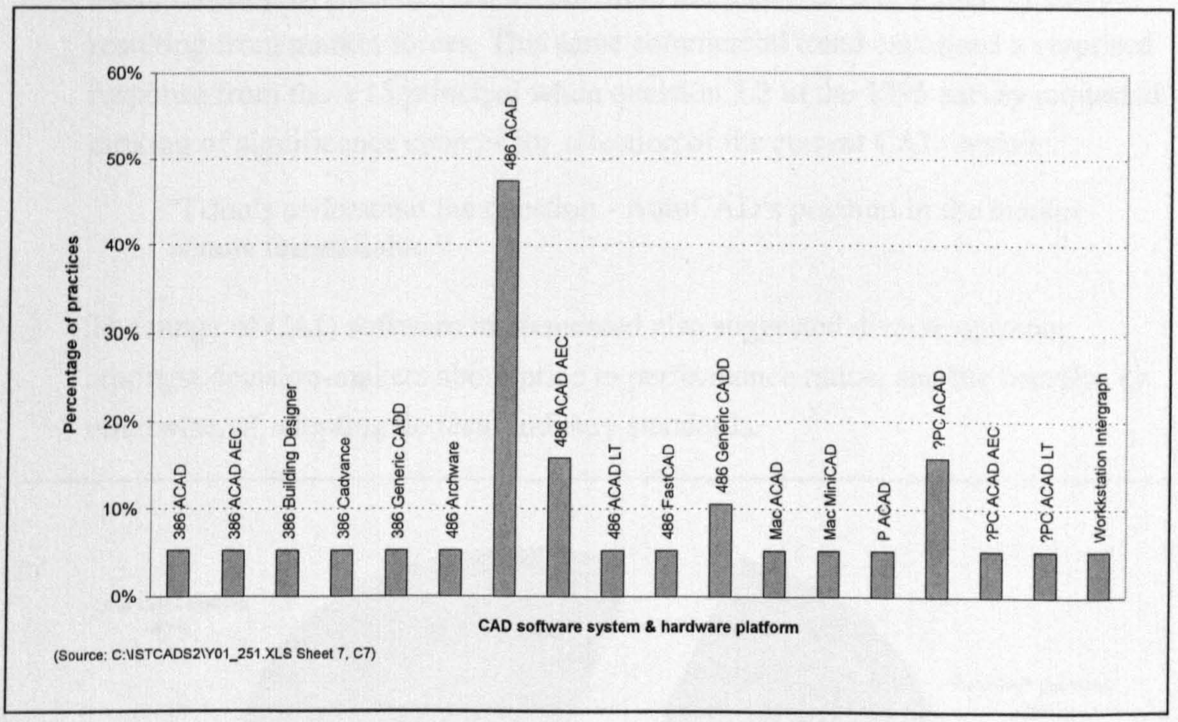


Chart 17 CAD hardware platforms and software systems installed by practices Y01-25 at 1995

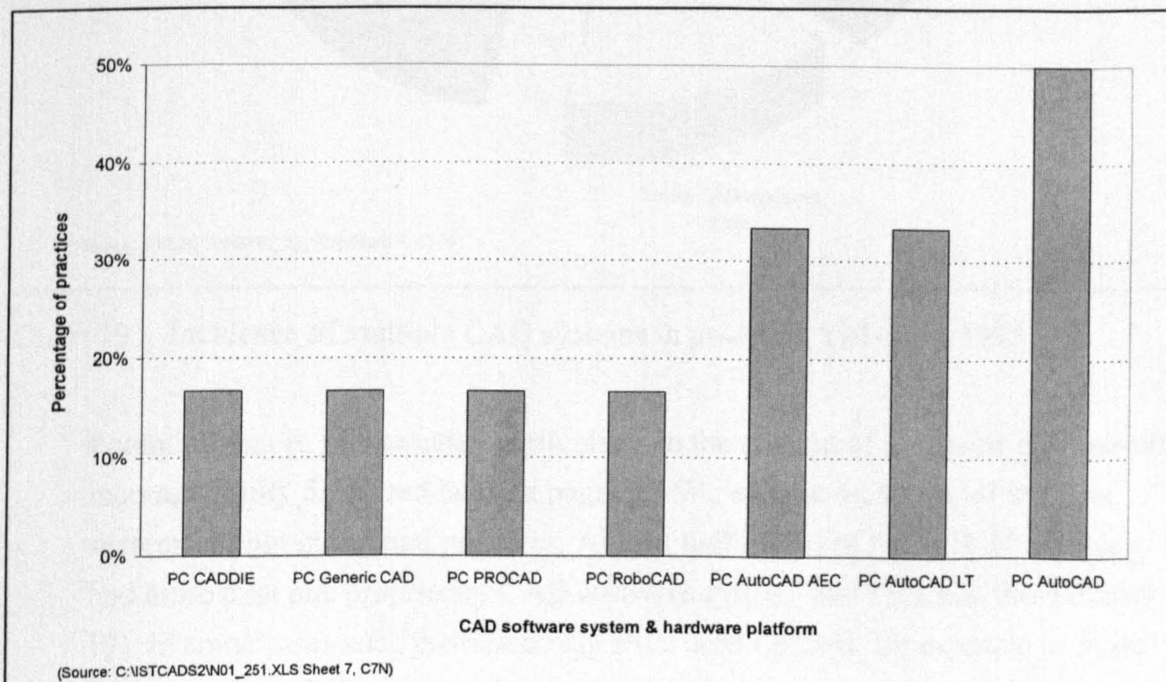


Chart 18 CAD hardware platforms and software systems and hardware platforms installed by practices N01-25 between 1993-95

More recent provision by N01-25 practices indicated the diminution of choice resulting from market forces. This same commercial trend explained a surprised response from the Y15 principal when question 3.2 in the 1995 survey requested ranking of significance sources for selection of the current CAD system:

> "I don't understand the question - AutoCAD's position in the market is now unassailable."

The range of CAD software implemented also suggested diverse opinions amongst decision-makers about price to performance ratios, and the benefits, or otherwise, of adopting de facto industry standards.

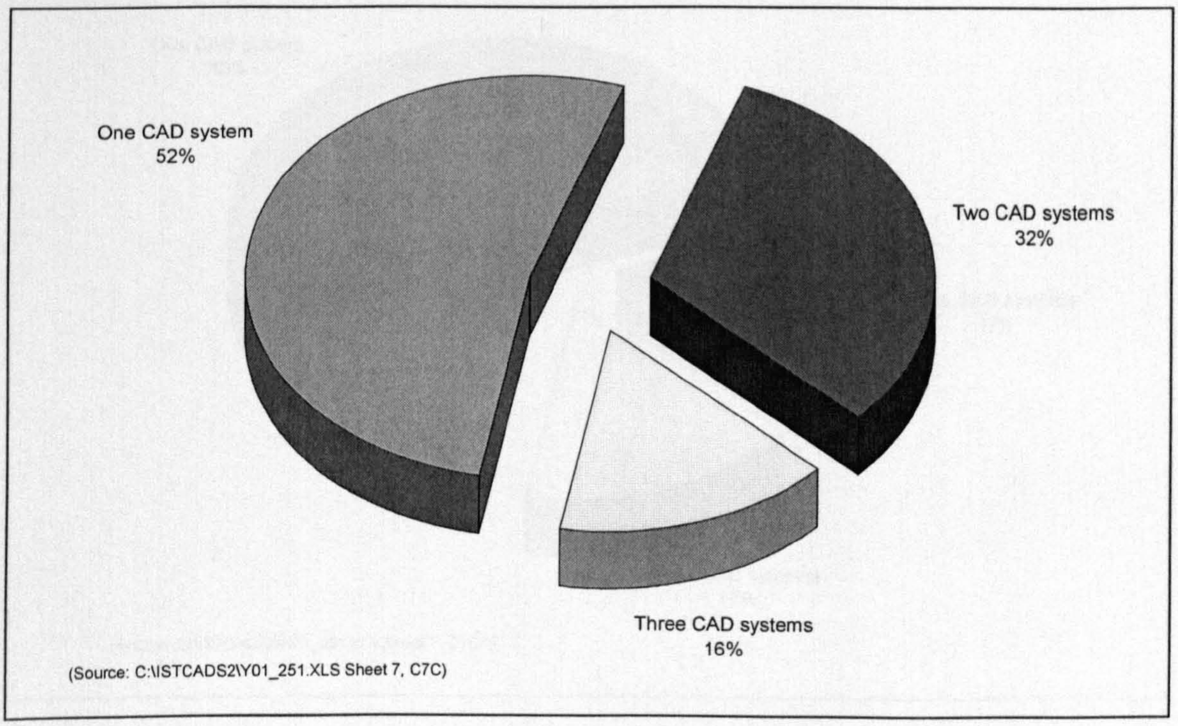


Chart 19 Incidence of multiple CAD systems in practices Y01-25 at 1995

Potentially more problematic, particularly in the context of problems with system incompatibility discussed later on pages 88-94, was the incidence of multiple systems within individual practices. Almost half (48%) of the Y01-25 sample had more than one proprietary CAD software system, and 16% had three (Chart 19). In some cases such provision may have been optimal, for example in those practices using different Autodesk products where purchase prices reflected different capabilities but the full AutoCAD system and the cut-down AutoCAD LT shared a compatible interface and data structure.

Diversity of software systems was not restricted to long-standing users of CAD satisfy evolving requirements in their second or third phase of acquisition. The 38% of N01-25 practices which had installed CAD between 1993 and 1995 were using a total of seven proprietary CAD systems of which four were Autodesk products (Chart 18, p85). Similarly, N01-25 practices with CAD also had an incidence of multiple software systems within the same practice (Chart 20). Leeds-based practice N08, the largest company in the sample, with 35 professional and technical staff, for example, had all four of these Autodesk software systems.

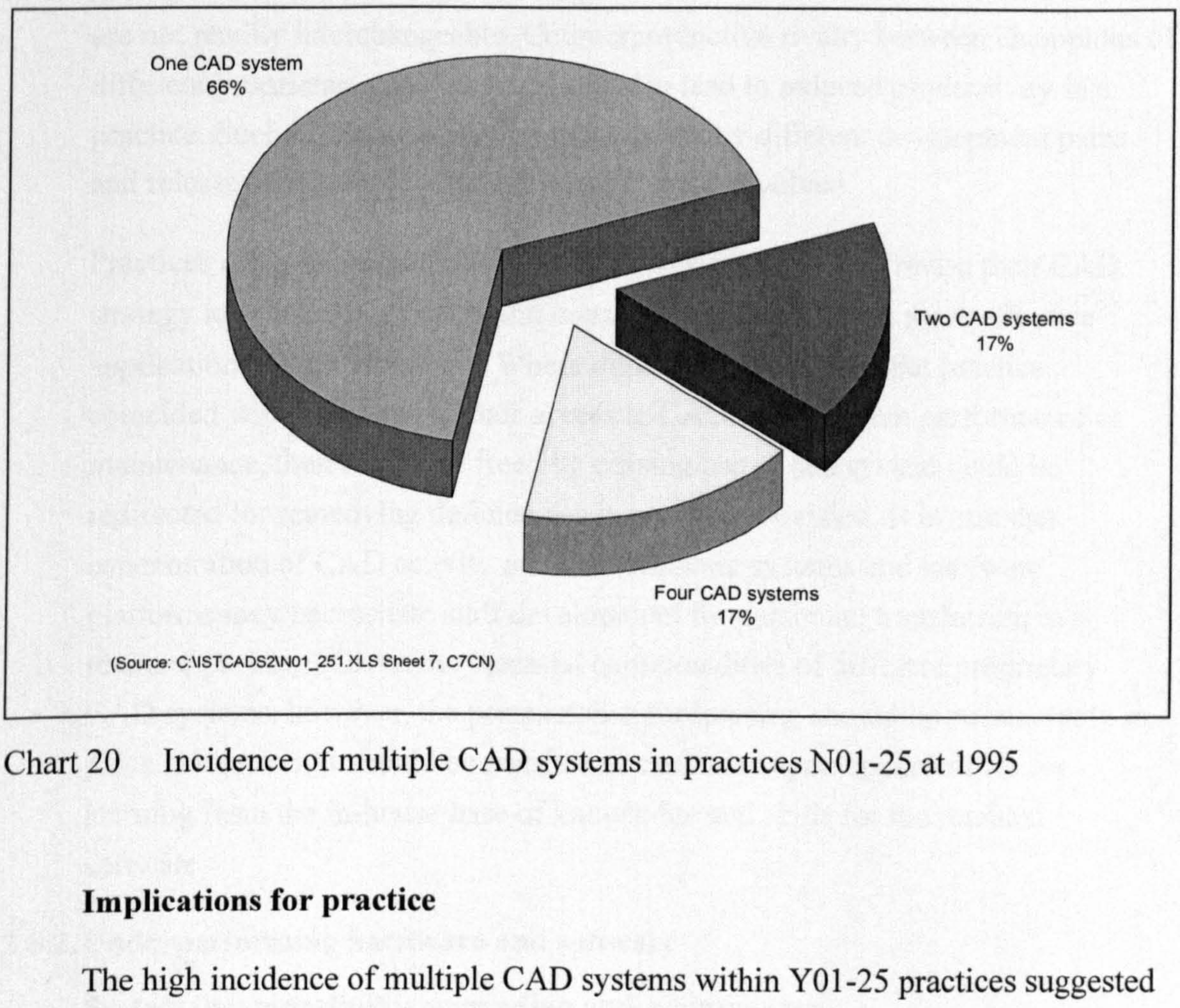


Chart 20 Incidence of multiple CAD systems in practices N01-25 at 1995

Implications for practice

The high incidence of multiple CAD systems within Y01-25 practices suggested some dissatisfaction with earlier provision, and potential for generating, or reinforcing, perception of the technology as inherently difficult. In reality a multiplicity of CAD systems need not be problematic in a practice if some software has effectively been discarded following an acceptable return on the initial purchase price and subsequent real costs of maintenance and staff development. It can cause problems, however, if different systems still in use for core activities by the same staff present incompatibilities, or are used by different staff who need to interchange digital data. Reduced productivity might be apparent in a lower return per unit of expenditure on CAD hardware, software or operators where systems differ operationally, use different data structures, or attract only partial take-up in the practice. Incompatibilities are typically readily apparent in reduced utility of symbols libraries and standard details within and between projects. Staff might also suffer reduced productivity from the additional burden of learning, using and maintaining different systems. Indeed the effectiveness of training might itself be constrained as a result. Opportunities for collaboration in learning applications software, developing application strategies, standardised formats and procedures also diminish when data and staff are not readily interchangeable. Counterproductive rivalry between champions of different proprietary CAD systems can also lead to reduced productivity in a practice. Such difficulties may be exacerbated by different development paths and release schedules for the software products involved.

Practices using more than one proprietary system needed to revise their CAD strategy to reduce duplication and consequent constraints on more effective application of the technology. Where duplicate provision in the practice coincided with problems of staff access to CAD seats, system performance or maintenance, then resources freed by ceasing use of one system could be redirected for remedying deficiencies in retained provision. It is true that concentration of CAD activity on fewer software systems and hardware platforms may necessitate staff development for personnel transferring to a retained package. Given the essential commonalities of different proprietary CAD systems, however, the prerequisites for learning should be substantially in place. Moreover, it should be possible to capitalise upon opportunities for learning from the in-house base of knowledge and skills for the retained software.

3.8.2. Underperforming hardware and software

System incompatibility, upgrading and maintenance

Effective use of CAD was constrained in Y01-25 practices of all sizes by underperforming hardware and software systems (Chart 10, p69). Six different types of hardware were being used across the sample to run its CAD systems at 1995. Applying criteria generally accepted at the time, this range of platforms could be divided into hardware for which processing capabilities were either obsolete, standard or advanced, as shown in Chart 21, p89.

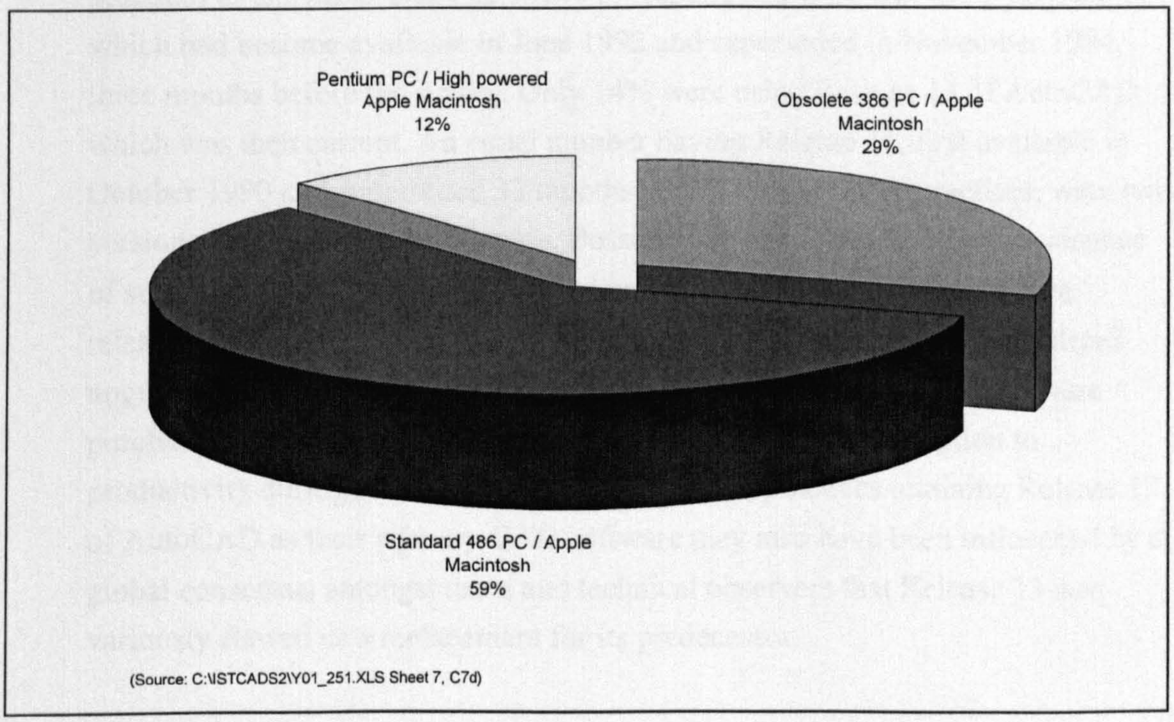


Chart 21 Performance of CAD hardware platforms in practices Y01-25 at 1995

Of constraints experienced, system incompatibility was the second most common problem for the whole sample with an incidence of 65%. 58% of all practices had experienced problems upgrading their CAD system(s), and 37% had difficulty with system maintenance. Incidence of these difficulties varied with the size of practice. Whilst for small practices system incompatibility was the most widespread problem, and upgrading the second most prevalent, they had more than double the incidence of problems with upgrading their systems than medium sized practices. The impact of constraints on system performance was also substantially greater in small practices. A correlation of only 0.17 was found for all respondents between the incidence of problems with system incompatibility and those experienced with applying CAD to specific tasks. For small practices the coefficient was 0.88. At 0.67 small practices also had a higher correlation than the whole sample between the incidence of problems upgrading systems and those experienced with applying CAD to specific tasks.

Use of obsolete software

At 1995 47% of respondents were using industry standard AutoCAD software on 486 personal computers. Whilst this was the most common combination of hardware and software (Chart 17, p85), the system release varied between practices as shown in Chart 22[1]. 72% of respondents were still using Release 12 which had become available in June 1992 and superseded in November 1994, three months before the survey. Only 14% were using Release 13 of AutoCAD which was then current. An equal number having Release 11, first available in October 1990 and superseded 32 months before the survey of practices, were two versions behind the current release. Possible explanations for the predominance of superseded CAD software included practices being unaware of the new release, or still considering upgrading. Alternatively, practices had considered upgrading but were unwilling or unable to incur additional costs of software purchase, hardware upgrade, update training and potential disruption to productivity during the transition. A proportion of practices retaining Release 12 of AutoCAD as their primary CAD software may also have been influenced by a global consensus amongst users and technical observers that Release 13 was variously flawed as a replacement for its predecessor.

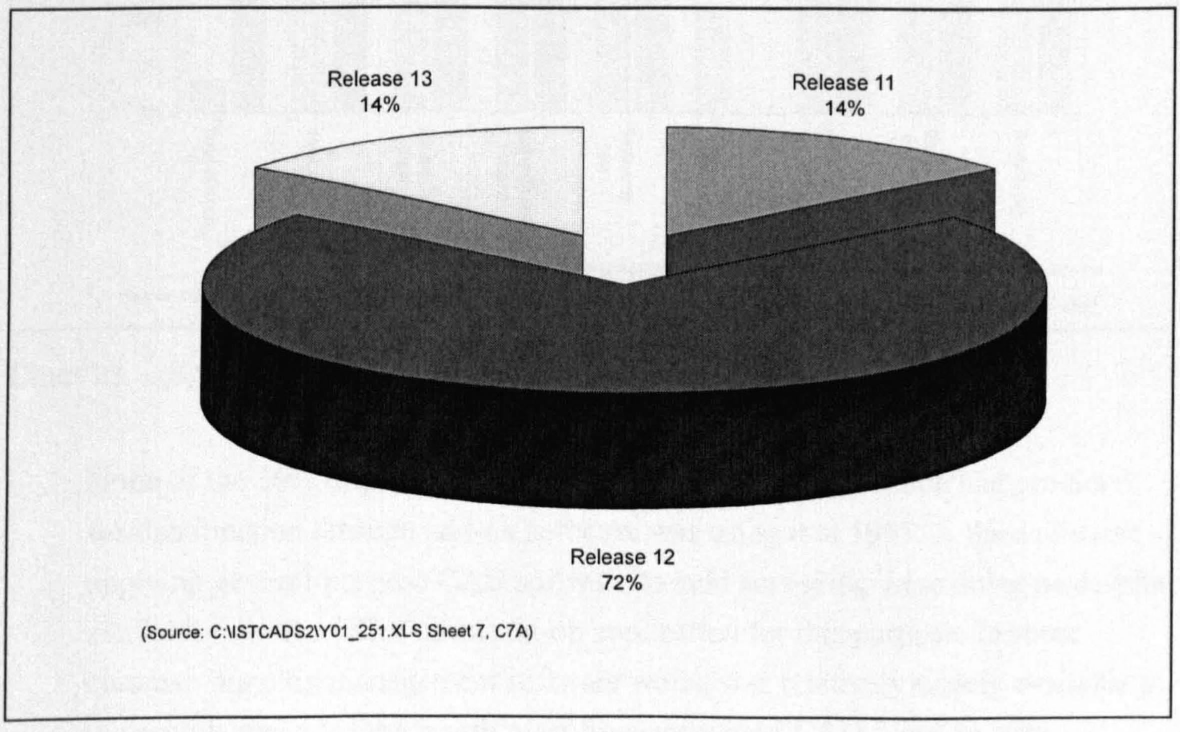


Chart 22 Release of AutoCAD used by practices Y01-25 at 1995

1 Refers only to the 50% of AutoCAD using practices in the Y01-25 sample which specified their release of AutoCAD in 1995

Low use of specialist software

There was evidence from the sample that provision and use of specialised add-on software was problematic (Chart 23). Availability and application of AEC, the Architectural, Engineering and Construction extension to the base AutoCAD software system, for example, had a relatively low uptake at only 26% of the sample.

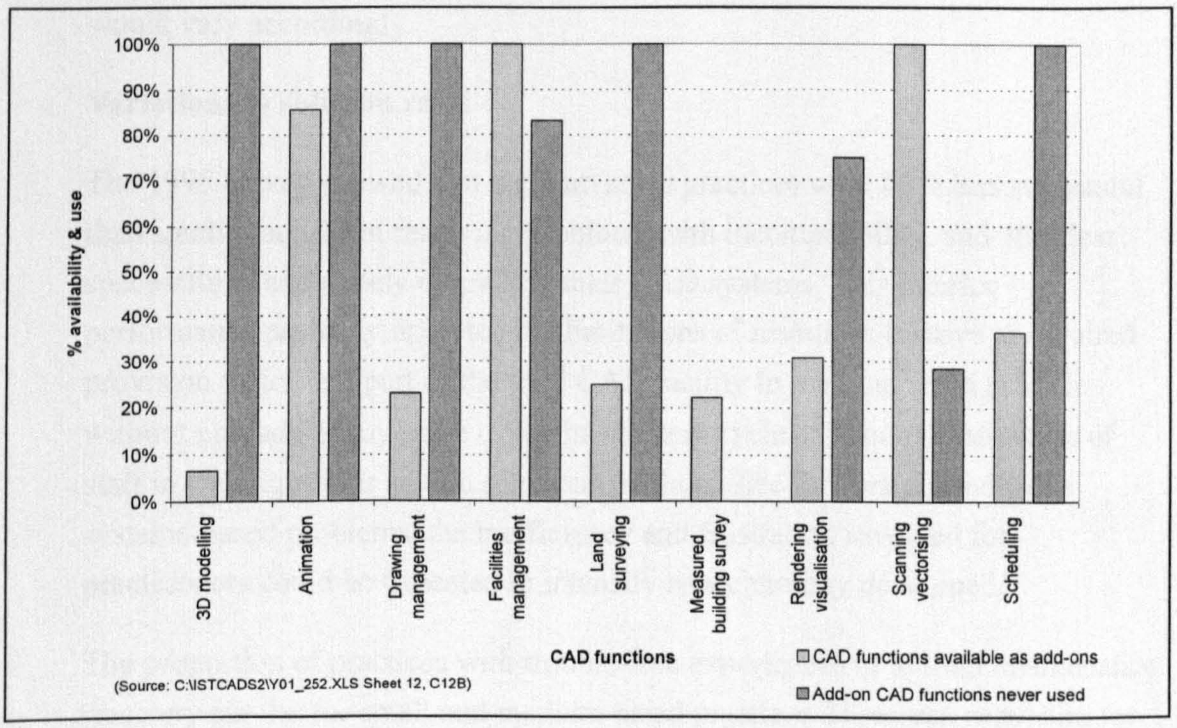


Chart 23 Specialised add-on software in practices Y01-25 at 1995

None of the 36% of practices with scheduling capabilities which had provided for this function through add-on software was using it at 1995. A third of those applying general-purpose CAD software to land surveying were doing so despite availability in the office of an add-on application for this purpose. In some contrast, drawing management software which was relatively widely available in the sample provided the fourth most frequently used CAD function with 14% more regular use than the median (24%) for all ten CAD functions (Chart 15, p80). Even so, when 89% of respondents with drawing management capabilities were regularly using their systems for 2D drafting, and potentially generating files at sufficient rate to benefit from drawing management capabilities, regular use of only 38% for this software was surprisingly low.

Alternative explanations for these results include acceptance that those specialised applications purchased were either not needed, or had proved inadequate, for the actual requirements of workload. Practices with specialised software systems might also have experienced organisational difficulties, or a gap in skills which limited their use. Undertaking work instead within the constraints of general-purpose software and existing capabilities of staff may have been a response to such difficulties. The extent to which such explanations, or an otherwise flawed CAD strategy, applied in a particular practice required investigating locally. Any recommendations for appropriate training solutions would vary accordingly.

Variations in solution rates

The 1995 survey showed that medium sized practices were 60% less successful than small practices at resolving problems with incompatibility, and 56% less successful at adequately upgrading their CAD systems. This inferior performance probably reflected the limitations of resources relative to required provision which left part of the total CAD facility in medium sized practices without upgrade at any stage of the investment cycle. Although instruction of staff in techniques for ad hoc solutions might suffice to work around these systems-based problems, the inefficiency and frustration involved for practitioners could be expected to intensify as technology developed.

The proportion of practices with trouble-free experiences of system maintenance was very similar for small and medium-sized practices. However, provision for maintenance of CAD hardware and software varied considerably between practices and 37% had experienced problems maintaining their CAD systems (Chart 24, p93). Large practices had more extensive maintenance cover for CAD hardware and software than those of medium-size. The latter, in turn, had a substantially higher incidence of maintenance agreements than small practices where provision for maintenance was very low. Only a third of all practices with networked CAD covered that part of their system with a maintenance agreement (Chart 24).

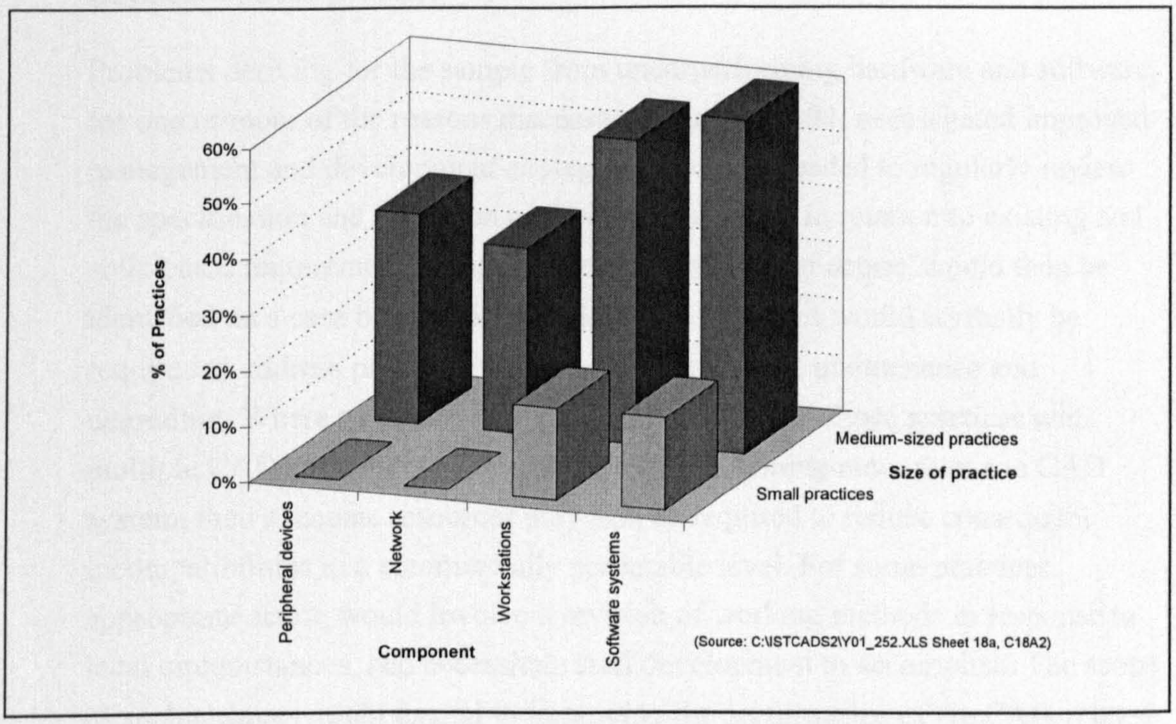


Chart 24 Maintenance agreements for CAD systems in practices Y01-25 at 1995

In addition to the obvious disruption and loss of productivity caused directly by malfunctions, practices with inadequate provision for maintenance of their systems could expect detrimental effects on the use of CAD from two other sources. Firstly, working environments would tend to become additionally stressful because of suboptimal performance of hardware or software, and the prospect of protracted system failure. Secondly, knowledgeable staff were prone to periodic diversion from productive application of CAD in order to resolve malfunctioning systems. On such occasions identifying and applying fixes was likely to take longer without support from original suppliers or capable third parties.

Practices with networked CAD, but without maintenance provision to remedy network failure, needed to review the potential costs of extended downtime. Use of subsequent technical developments enabling distribution of project data via the Internet, and purpose-built project hosting services, for example Autodesk's Buzzsaw portal through the World Wide Web (WWW), have since increased the vulnerability of practices to network failure.

Implications for practice

Problems deriving for the sample from underperforming hardware and software, for one or more of the reasons discussed on pages 88-93, necessitated improved management and development strategies. Practices needed to regularly review the specification and operation of their CAD systems in relation to existing and anticipated requirements. Appropriate combinations of action should then be identified on a case by case basis. Additional resources would normally be required to address problems with system acquisition, maintenance and upgrading. Where an informed and objective review in those practices with multiple CAD systems concluded in favour of retaining more than one CAD system, then adequate resources may also be required to reduce consequent incompatibilities to a commercially acceptable level. For some practices appropriate action would involve a revision of working methods in response to local circumstances, and necessitate staff development to accomplish. The scope of such changes might extend to improving the performance of the CAD-related tasks discussed on pages 110-117. Enhancements may, for example, be possible in day-to-day supervision of hardware and software, including file management to reduce demands on storage and processing. Positive variations in scheduling work throughput might ease the burden of laborious processes on staff and constrained CAD systems. Similarly, staff development may be undertaken beneficially for familiarising personnel with relevant technical developments, including instruction and learning to exploit opportunities in networked CAD, and identify future uses of the technology. Although staff development and selective adjustment of working methods might contribute to reducing the negative effects of underperforming hardware and software their effectiveness is likely to be limited by comparison to appropriate resource action.

3.8.3. Constraints on system availability and use

Effective application and development of the CAD capabilities in a practice requires use of relevant resources by personnel who are either already suitably skilled for their application to authentic components of workload, or are developing CAD knowledge and skills through instruction, learning, reinforcement and practice. In reality an individual member of staff may display both characteristics concurrently, and need to use the same CAD resources for the two purposes during a given period of time. Progress with either activity is dependent upon simultaneous availability of hardware, software and staff on predetermined occasions of predictable duration, and for ad hoc periods of less prescient length. Conflict which may occur between these two requirements is likely to constrain effective application of CAD to the workload of the practice, and appropriate development of its staff and application strategies for CAD. These problems may be intensified by underperforming hardware or software extending the duration of working sessions required to achieve satisfactory results for either purpose. Providing effectively for both mainstream applications of CAD, and associated staff development, requires disaggregation of the constraints which limit coordinating availability of the essential components, that is staff and CAD workstations.

Relationships between CAD seats, total professional and technical staff, and the CAD users amongst them in the Y01-25 sample at 1995 are summarised in Chart 25 and Table 12 (p96). The average number of CAD seats in a practice for the sample as a whole was 2, and ranged from 1.5 in small practices to 2.2 in those of medium size. The average number of CAD users for the sample as a whole was 4.2 and ranged from 2.3 staff at any interval in small practices to 4.5 in medium sized practices. Corresponding averages for CAD users at daily or weekly intervals were 3.6, 2 and 3.6 respectively.

Using the ratio in a practice between its CAD seats and those staff using CAD at daily or weekly intervals as an indicator of hardware and software availability, the Y01-25 sample as a whole had a negative correlation of -0.36 between this ratio and the overall index of benefits from the technology ((Daily CAD users : CAD seats) : Benefits). In other words benefits derived by practices as a whole from using CAD tended to decrease as more staff competed for use of limited hardware and software. The equivalent correlations for small and medium sized practices were -0.22, and -0.36 respectively.

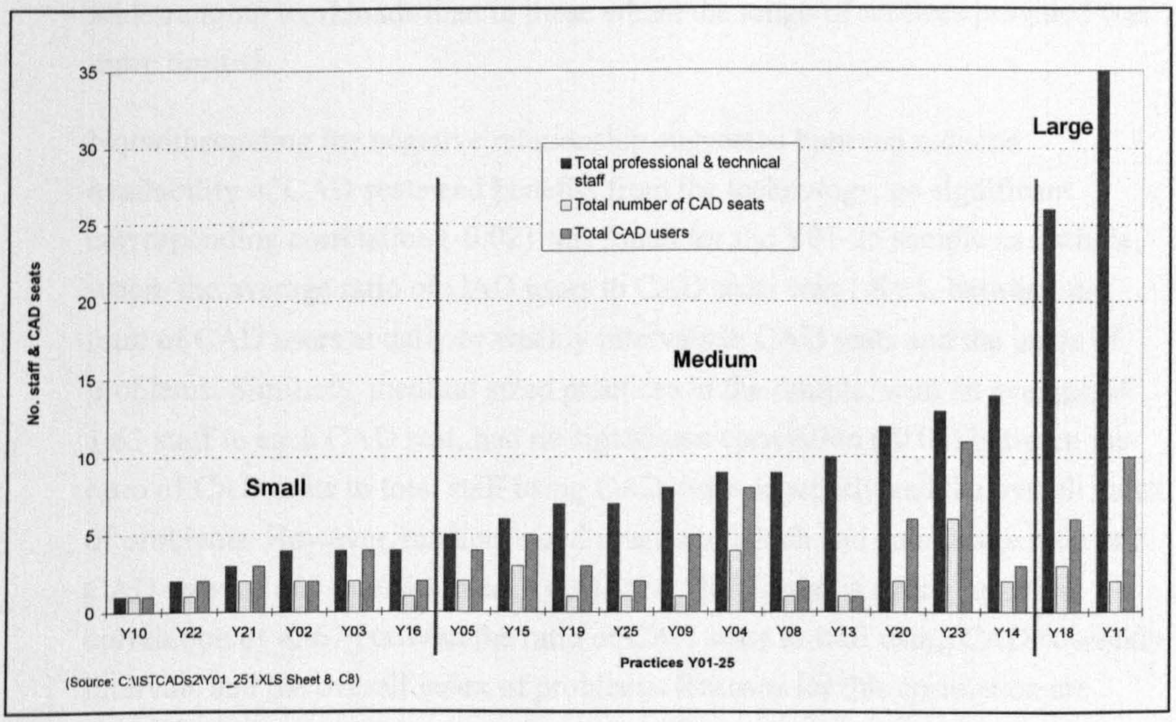


Chart 25 Relationship between CAD seats, total staff and CAD users in practices Y01-25 at 1995

Size of practice (NA Staff)	Average total staff	Average CAD seats	Average CAD users at any interval	Average CAD users : Daily / weekly
All	9.42	2	4.2	3.6
Small (1-4)	3	1.5	2.3	2
Medium (5-14)	9.1	2.2	4.5	3.6

Table 12 Ratio of CAD seats to CAD users in practices Y01-25 at 1995

Although the sample size for large practices did not allow calculation of correlations, the large practice (Y18) with a higher overall index of benefits at seven from a potential maximum of eight had a ratio of staff making any use of CAD to available CAD seats of only 2:1 by comparison to a ratio of 5:1 in the practice (Y11) achieving a lower index of five. These two cases suggests that the incidence of lower ratios of user to workstation also coincided with higher overall benefits from CAD in large practices. It should be acknowledged, however, that opportunities for achieving benefits from a relatively small number of CAD seats were likely to be more apparent in large practices with wide-ranging workloads than in those where the range of services provided was more limited.

Notwithstanding the negative relationship suggested between reduced availability of CAD seats and benefits from the technology, no significant corresponding correlation (-0.02) was found for the Y01-25 sample as a whole, where the average ratio of CAD users to CAD seats was 1.8 : 1, between the ratio of CAD users at daily or weekly intervals to CAD seats and the index of problems. Similarly, medium sized practices in the sample, with an average of 1.63 staff to each CAD seat, had no significant correlation (-0.08) between the ratio of CAD seats to total staff using CAD daily or weekly and the overall index of problems. However, medium sized practices, which had an average ratio of 2 CAD users at any interval to each CAD seat, did display a strong negative correlation of -0.67 between the ratio of CAD seats to staff using CAD at weekly intervals and the overall index of problems. Reasons for this correlation are likely to have included the high incidence (60%) of concurrent problems with training for CAD, with retaining CAD-skilled staff (55%) who might have become frustrated with restricted access to CAD workstations, and incompatibility (40%) arising through enforced use of different and incompatible CAD software systems (Chart 11, p71). For small practices, however, with an average of 1.33 users to each CAD seat, a correlation of 0.39 was found between their overall index of problems with CAD and the ratio of professional or technical staff using CAD daily or weekly to the number of CAD seats in the practice. In other words the index of problems for small practices, where the average ratio of CAD users at any interval to CAD seats was 1.5 : 1, tended to increase as the number of CAD users sharing workstations increased. Reasons for the correlation probably derived from the single or combined effect of those problems with the highest concurrent incidence for small practices (Chart 12, p71), that is making specific applications of CAD (40%), training staff to use available systems (33%), and compatibility between CAD systems (40%). The large practice with the highest ratio of CAD users to CAD seats (5:1 at any interval, or daily or weekly intervals, and 3.5:1 at weekly intervals) also had at four out of 16 the lowest overall index of problems with the technology. The other large practice, with an overall index of problems of 14 out of 16, had ratios of 2:1, 2:1 and 1:1 respectively. The better performing practice, however, had never experienced problems in four of the eight categories investigated, and had resolved them in the remainder. By comparison, the large practice with relative underperformance had experienced difficulties in all eight aspects, and problems were continuing in six of these. These two cases suggested that considerable success was achievable with CAD in large practices despite high ratios of CAD users to CAD workstations, but also indicated the possibility of experiencing a wide range of difficulties beyond constrained availability of hardware and software.

Frequency of use and availability of staff

Correlations between the extent and frequency of use of CAD and the overall index of benefits from CAD in practices Y01-25 are summarised in Table 14c1.

Factors : Index of benefits	Correlation		
	All practices	Small practices	Medium sized practices
% Professional staff using CAD daily	0.4	0.55	0.36
% Professional staff using CAD weekly	0.1	0.32	-0.22
% Professional staff using CAD daily or weekly : Index of benefits	0.38	0.74	0.14
% Technical staff using CAD daily	0.42	0.63	0.33
Total professional and technical staff using CAD at any frequency : CAD seats	-0.18	0.23	-0.2
Total professional and technical CAD sessions per week	0.4	0.76	0.51
Ratio of total professional and technical CAD sessions per week : CAD seats	0.32	0.77	0.36

Table 14c1 Correlations between extent and frequency of use of CAD and the overall index of benefits from CAD in practices Y01-25 (Source: Y01_252.XLS, Sheet 16)

For practices as a whole a correlation of 0.4 was found between the total number of sessions in which professional and technical staff worked with CAD in a week and the overall index of benefits from using the technology. This rose to 0.51 for medium sized practices, and to 0.76 for small practices. Similar positive relationships were found between benefits achieved and the intensity with which systems were used. A coefficient of 0.42 was found between the percentage of technical staff using CAD daily and the overall index of benefits from the technology. The correlation rose to 0.63 in small practices but fell to 0.33 in those of medium size. A corresponding pattern was evident relating the percentage of professional staff using CAD daily to the overall index of benefits, with coefficients of 0.4, 0.55 and 0.36, in all, small and medium sized practices respectively. Positive coefficients were also found at 0.32, 0.77 and 0.36 in all, small and medium sized practices respectively between the overall index of benefits from CAD and the ratio between CAD sessions per week by all professional and technical staff and CAD seats. Small practices in the Y01-25 sample had a correlation of 0.23 between the overall index of benefits from CAD and the ratio of total professional or technical staff using CAD at any frequency to CAD seats. Moreover, a correlation of 0.77 was found for small practices in the Y01-25 sample between their index of benefits from CAD and the ratio between the total number of CAD sessions per week by professional and technical staff and CAD seats.

Chart 26 (p102) summarises the percentages of all professional and technical staff making use of CAD at daily, weekly, or less than weekly intervals in practices Y01-25 at 1995. The median numbers of staff involved at these intervals are shown for the whole sample, and for different sizes of its constituent practices, in Table 13 (p100). In the sample as a whole, and in medium sized and small practices the median was for one in three of all staff using CAD to do so at less than weekly intervals. 83% of those respondents in the Y01-25 sample with two or more non-administrative staff were operating an in-house service whereby CAD work was undertaken on behalf of others in the practice. Although a significant median percentage (43%) of the professional and technical workforce made some use of CAD, the standard deviation for uptake at any interval was 29.6, and wide variations were consequently evident between practices. Norfolk-based practice Y13 had an uptake of only 5% compared to 100% in Y03 of Poole, and practice Y21 of Chelmsford.

For Y01-25 practices as a whole only 14% of professional and technical staff made use of CAD on a daily basis (Table 13), and the median was for just one member of staff in a practice to use CAD daily. A median of 3 staff, or 29% of technicians and professionals, were using CAD at only weekly intervals or less frequently. In small practices the median total staff using CAD at any interval rose to 57% although the median daily use, and weekly or less frequent use, remained at 14% and 29% respectively. In medium sized practices a median of 44% of all technicians and professionals were making some use of CAD. For these practices the median daily uptake was marginally lower than for small practices at 11%, and a corresponding increase to 33% was evident in the median percentage of total staff using CAD weekly, or less frequently.

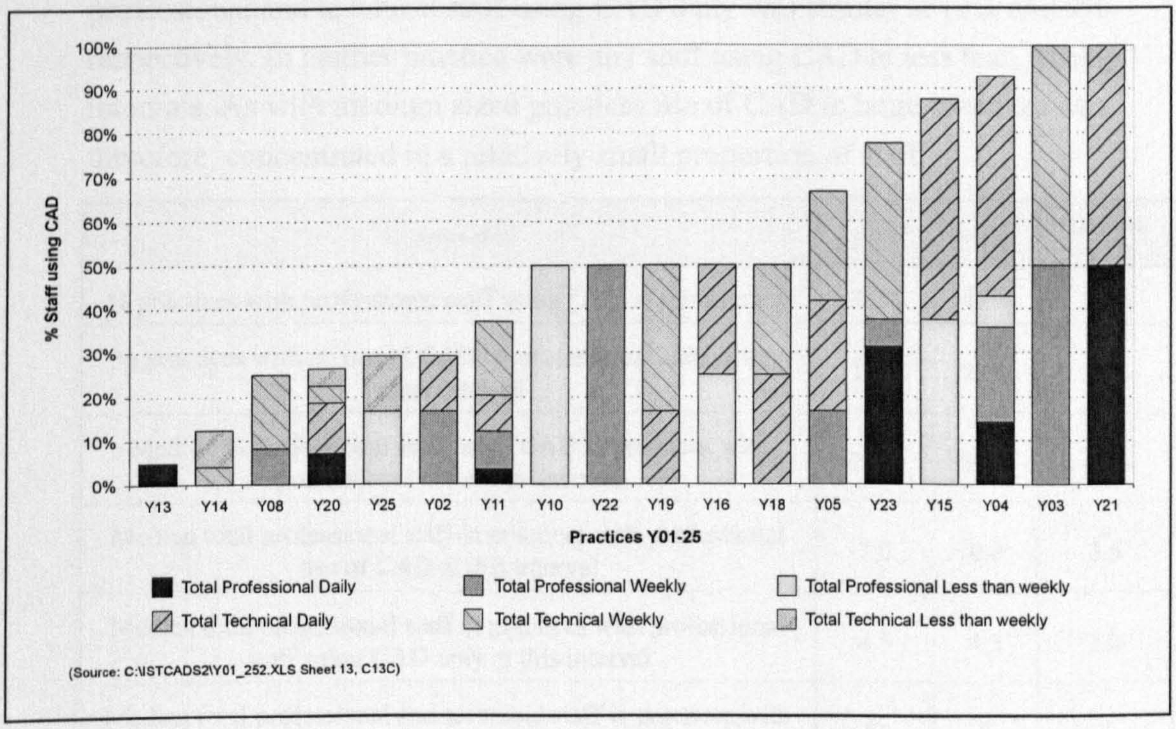


Chart 26 Frequency of use of CAD by type of staff in practices Y01-25 at 1995. (Sorted by total number of staff) (Source Y01-252.xls, Sheet 13, F178:R195)

	Use of CAD				
Size (NA staff)	Median total staff at any interval	Median % staff at any interval[1]	Median total staff daily	Median % staff daily	Median % staff weekly or less frequently
All	3	43%	1	14%	29%
Small (1-4)	2	57%	0.5	14%	29%
Medium (5-14)	4	44%	1	11%	33%

Table 13 Median use of CAD by professional and technical staff in practices Y01-25 at 1995 (Source: Y01-251.xls, Sheet 8, "Summaries)

1 Median percentages calculated by dividing the median staff using CAD at the specified interval by the median total staff in the practice.

The large practice (Y18) with the higher overall index of benefits from CAD had 23% of its total professional and technical staff using CAD at any interval, compared to 29% in practice Y11. In both practices the percentage of total professional and technical staff using CAD daily was similar at 12% and 9% respectively. In neither practice were any staff using CAD at less than weekly intervals. As with medium sized practices use of CAD in large practices was, therefore, concentrated in a relatively small proportion of staff.

Frequency of use	Daily	Weekly	Less than weekly
% practices with professional staff using CAD at this interval	33%	47%	27%
% practices with no use of CAD by professional staff at any other interval	13%	27%	20%
Median % professional staff using CAD in practices with professional use at this interval	29%	33%	42%
Median total professional staff in practices with professional use of CAD at this interval	7.0	6.0	3.5
Median total professional staff in practices with professional staff using CAD only at this interval	4.5	4.5	3.0
Median total professional and technical staff in practices with professional staff using CAD at this frequency	13	9	7
Median total professional and technical staff in practices with professional staff using CAD only at this frequency	12	8	6

Table 14 Frequency of use of CAD by professional staff in practices Y01-25 at 1995 (Source: Y01-252.xls, Sheet 13)

With respect specifically to use of CAD by professional staff in Y01-25 practices, summarised in Table 14, the Y01-25 sample displayed an even higher standard deviation of 35.98 in the recorded percentages of personnel using the technology at any interval, and uptake varied correspondingly between practices. In only 33% of Y01-25 practices were professional staff making direct use of CAD on a daily basis[1] and for those practices involved the median incidence was for just 29%. Across this section of the sample the percentage of total professional staff involved ranged from 7% in Bromley-based Y11 to 100% in

1 Comparisons between use of CAD by professional and technical staff exclude practices Y10, Y13 and Y22, (17% of the sample), which had no technician staff at 1995, representing a special case for analysis.

Y21 at Chelmsford. The clear tendency was for only a small proportion of professional staff in the sample as a whole to use CAD on a daily basis. Moreover, the median total professional and technical staff in practices where professional staff used CAD daily was 13, suggesting that daily use of CAD by professional staff tended to occur in the larger of medium sized offices. In medium sized practices with a smaller workforce professional staff tended to use CAD only at less than weekly intervals. These statistics obtained from the 1995 survey corroborate discussions with practitioners in the early stages of the research programme which indicated that professional staff tended to avoid using CAD more frequently and thereby becoming de facto CAD technicians, with undesirable consequences for their career development and progression.

Relationships between technicians, professionals and use of CAD in practices Y01-25 at 1995 are summarised in Table 14b (p103). A coefficient of -0.39 was found between the total number of professional staff using CAD at any interval and the total number of professional staff in the practice. A much higher coefficient of -0.61 was found for the whole Y01-25 sample between the total number of professional staff using CAD at any interval and the total number of technical staff in the practice. Fewer professional staff used CAD in practices, therefore, as the number of professional staff in the practice rose and the tendency strengthened substantially as the number of technicians in the practice increased. When the correlation of -0.38 found between the total number of professional staff using CAD weekly in practices Y01-25 and the total number of technical staff in the practice is considered in conjunction with a negative correlation of -0.3 for the relationship involving use of CAD by professional staff at less than weekly intervals it is clear that the tendency extended into use of the technology at less regular intervals.

A correlation of -0.58 was found for the whole Y01-25 sample between the total number of professional staff using CAD daily and the total number of professional staff not using CAD at all. This coefficient indicated a strong tendency for frequent use of CAD to become a specialised function for professional staff. A correlation of 0.58 was found between the total number of professional staff using CAD daily and the total number of professional staff making any use of CAD. The coefficient relating the total number of professional staff using CAD daily and the total number of technical and professional staff making no use of CAD was -0.52.

Factor 1	Factor 2	Correlation
Total technical staff using CAD at any interval	Total technical staff	-0.54
Total technical staff using CAD daily	As above	-0.42
Total technical staff using CAD weekly	As above	-0.17
Total technical staff using CAD less than weekly	As above	0.47
Total professional staff using CAD at any interval	As above	-0.61
Total professional staff using CAD daily	As above	-0.16
Total professional staff using CAD weekly	As above	-0.38
Total professional staff using CAD less than weekly	As above	-0.3
Total professional staff using CAD at any interval	Total professional staff	-0.39
Total technical staff making any use of CAD	As above	-0.03
Total technical staff using CAD daily	As above	-0.15
Total technical staff using CAD weekly	As above	0.17
Total technical staff using CAD less than weekly	As above	-0.12
Total professional staff using CAD daily	Total professional staff making no use of CAD	-0.58
Total technical staff using CAD daily	Total technical staff making no use of CAD	-0.61
Total professional staff using CAD daily	As above	-0.31
Total technical staff using CAD daily	Total technical staff making any use of CAD	0.61
Total technical staff using CAD weekly	As above	0.45
Total technical staff using CAD less than weekly	As above	-0.58
Total professional staff using CAD daily	Total professional staff making any use of CAD	0.58
Total technical staff using CAD daily	Total technical and professional staff making no use of CAD	-0.61
Total professional staff using CAD daily	As above	-0.52

Table 14b Relationships between technicians, professionals and use of CAD in practices Y01-25 at 1995 (Source: Y01-252.xls, Sheet 13)

Application of similar analysis to use of CAD by technical staff identified a correlation of -0.54 between the total number of technicians using CAD at any interval and the total number of technicians in the practice. A further coefficient of -0.42 was found between the total number of technical staff using CAD daily and the total number of technical staff in a practice. These results indicated, as for professional staff, that use of CAD became a specialised function for technicians as their number increased in a practice. A correlation of -0.61 between the total number of technical staff using CAD daily and the total number of technical and professional staff not using the technology at all also indicated an overall tendency for polarisation of use by technicians. No significant correlation was found between the number of technicians using CAD at different intervals and the total number of professional staff in a practice (Table 14b, p103).

Concern of the 1995 survey with problems of availability of staff for use of CAD focused upon a capacity in the workforce for using the technology more frequently for authentic purposes but which practices were constrained from realising by work-related factors other than the limited access to CAD seats discussed on pages 95-98. In addition to consequent difficulties of capitalising upon existing skills, irregular use of CAD could also be expected to limit development and retention of relevant knowledge and understanding of the technology and capabilities for its application. Distinguishing between the factors which contributed to these various performance deficiencies would help clarify the relative need for management, resourcing or training action.

Analysis of the 1995 survey data identified a correlation of 0.37 between the incidence of problems with availability of CAD-skilled staff and the percentage of technicians using CAD only at weekly intervals. The coefficient rose to 0.43 when considering less frequent use of CAD by technicians. These results suggest that technical staff in an appreciable proportion of practices were capable of productive application of the technology. Indeed, a coefficient of 0.47 relating the total technical staff using CAD at less than weekly intervals and the total number of technicians in Y01-25 practices indicated a broadening range of capability as the number of technicians increased. However, such staff appeared to be constrained from actually using CAD by factors other than inadequate capabilities with available software systems. A correlation of 0.45 between the number of technical staff using CAD at weekly intervals and the total number of technical staff making any use of CAD indicated a tendency for use of CAD at weekly intervals to rise as more technicians used CAD in a practice. The negative correlation found for professional staff may have indicated their direct use of the technology on a weekly basis to compensate for limited availability of technicians for such work. Further evidence of constrained availability of

CAD-skilled staff was indicated by the absence of a correlation between the incidence of problems with availability of CAD-skilled staff and the medium-term priority of practices for more technical staff using the technology. Moreover, only a weak correlation of -0.14 was identified between the same factors in the long-term. These results are consistent with requirements of practices to overcome problems of staff availability through intensifying use of the technology by technicians with existing capabilities, rather than increasing the number of technicians using CAD per se. With respect to professional staff, practices demonstrated a correlation of 0.19 in the medium-term, rising to 0.26 in the long-term, between the incidence of problems with availability of CAD-skilled staff and priorities for more professional staff using the technology. These results are consistent with a relative lack of CAD knowledge and skills amongst professional staff and the implied need for enabling their more widespread capability to engage productively with the technology.

Implications for practice

Results reported above indicate the benefits of moderating de facto in-house CAD bureaus with wider uptake and more frequent use of CAD, including opportunities to remedy limited development and accelerated erosion of CAD capabilities. They also highlight potential consequences of limited availability of staff and CAD seats for instruction, learning, reinforcement and practice. A further need is apparent to research relationships between the frequency and distribution of use of CAD and the problems and benefits experienced in a representative sample of practices, as well as the corresponding constraints for individual offices.

The high incidence of in-house CAD bureaus (83%), in conjunction with expressed priorities of the sample for extending their user base, indicated that application of CAD was concentrated in an undesirably small proportion of staff in many medium sized and large building surveying practices. Given the constraints identified on the availability of CAD seats, and a high incidence of problems with training, the recorded concentrations of use observed were occurring extensively as the most pragmatic options in the prevailing circumstances (Table 13, p100). Although in-house bureaus were not necessarily, therefore, the preferred strategy for implementing CAD in a practice, the extent to which respondents wished to expand the size of their bureaus, or to supplement them with more widespread use of the technology across the practice, required further investigation.

Evidence from analysing the 1995 survey results endorsed expansion of the user base by showing that wider distribution and higher frequencies of use of relevant hardware and software by staff were significant factors in determining the benefits and problems practices experience from their CAD system(s). Where use of CAD is intermittent, or of only limited durations, then staff capabilities can be expected to develop less rapidly and erode more extensively between working sessions with the technology. In an optimal strategy a practice objectively assesses its requirements of CAD over an extended period and makes comprehensive provision for both authentic applications and staff to develop relevant CAD knowledge, understanding and practical abilities through sustained use of the technology for such applications. In this scenario staff concurrently develop knowledge, understanding and practical ability to a point were reinforcement and productive application may coincide in more frequent use of CAD. Where access to CAD seats or staff availability is constrained, as in a high proportion of the sample, then conflict between requirements to use CAD by skilled staff for authentic components of workload, and development of CAD capabilities by those less knowledgeable and skilled, is likely to restrict effective practice and appropriate development of personnel and application strategies. Constraints on availability of hardware, software and personnel for use of the technology limit the effectiveness of instruction and opportunities for staff development. Both deficiencies need substantial remedy to achieve successful CAD strategies.

Given the correlations identified between frequency and distribution of use, and the incidence of problems and benefits with CAD, providing not only for effective mainstream applications of CAD but also for associated staff development requires disaggregation of the constraints which limit coordinating availability of the two essential components in either activity, that is of staff and CAD workstations. Whilst reasons for a constrained use patterns have been examined as far as possible from available sources the relative effect of either factor, namely limited availability of CAD seats and staff to use them for applications or staff development, could not be fully analysed from data collated in the current investigation. Further research is necessary in several respects. Continuing investigation is needed firstly in a representative sample of building surveying practices to identify the compounding effects, and implications for

CAD strategies, of deficiencies in the availability of hardware and software, and infrequent use of CAD by the majority of users. Notwithstanding the need for further investigation of relevant factors and relationships across a range of practices it is also necessary to acknowledge that diagnosing problems and prescribing solutions in general terms has limited utility for individual practices. Although in retrospect more detailed and less ambiguous data were needed to clarify issues of availability of CAD seats and CAD users, influential factors are likely to display unique combinations of predictability and uncertainty in different offices. The relative effects of constraints on system availability and frequency of use by staff need investigating for individual cases in order to make recommendations for particular CAD management and development strategies. The factors involved are extensively interrelated and require comprehensive, multifaceted treatment. A need for further research exists, therefore, at the level of the individual practice to establish the relative incidence and severity of relevant factors, and to distinguish interaction between constraints in order to inform appropriate remedial action. Objective assessment of staff availability is particularly important for small practices without technicians and where expectations of CAD may need moderating pending allocation of additional staff time for application and skills development. It should also be anticipated that the results from individual assessments and their implications for training will vary between practices, even between those of a similar size. Training staff either to start using CAD, or to improve the effectiveness of their existing capabilities, is likely to result in only a limited contribution to the overall benefits of CAD for the practice if those fundamental inadequacies discussed above persist in the specification, configuration, performance or compatibility of available hardware and software. Notwithstanding interpretation of results obtained in the preceding analysis, the author had retrospectively to acknowledge potential for different interpretations of the term "availability of CAD-skilled staff" by respondents to question 4.8 in the 1995 survey questionnaire (Appendix 2.1). In addition to the intended meaning of availability of suitably skilled staff within the practice for CAD-based work it was accepted that availability might also have been understood as the wider supply of suitably capable personnel in the market from which a practice could recruit staff. Responses received consequently provided potentially limited data for analysis of difficulties deriving from in-house availability of staff for use of software systems. Further research would consequently be needed to distinguish between the relative effects of these factors on the benefits and problems experienced by building surveying practices in their use of CAD. Consideration of system enhancement to overcome resource constraints on the effectiveness of CAD applications should also include consideration of action to remedy adverse effects on staff development.

(Next page 110)

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3.8.4. Inadequately collaborative working practices

The need for collaboration between participants in the construction industry was strongly argued by Latham (1994). Use of CAD systems in the same connection inherently depends upon collaborative activity. The routine event of running CAD software on a workstation in a practice is dependent upon extensive prior collective working by software developers in collaboration with practitioners followed up by local compliance with conventions for installing the system and making it operational. Proceeding to achieve effective use of the same CAD workstation throughout its economic life in a building surveying practice is typically a continuum of interaction between professional and technical staff within the office, and beyond its confines on joint projects. The process of obtaining initial project data from one or more sources, followed by decision-making on content and formats suitable for subsequent uses of the resulting drawings and models, often necessitates close collaboration. During this time periodic engagement with suppliers of hardware and software is usually required for selective support and guidance. In this context the 1995 survey of practices collated data on the extent of collaboration for five CAD-related tasks in the practice:

- File management.
- Day-to-day supervision of hardware and software.
- Scheduling work throughput.
- Familiarising with technical developments.
- Identifying future uses of CAD.

Distribution of CAD-related tasks in practices Y01-25

Results from the survey showed that at 1995 CAD-related tasks were distributed between professional and technical staff in Y01-25 practices as summarised in Chart 27 (p111). The highest incidence of joint responsibility (36%) in the full Y01-25 sample was for familiarising with technical developments. Professional staff performed this function on their own in a similar proportion of practices, whilst it was solely the responsibility of technicians in the remainder. The associated function of identifying future uses of CAD had at 25% the next highest incidence of joint responsibility, but professional staff had sole responsibility for doing so in more than twice as many practices (56%). The lowest incidence of collaboration (6%) was for day-to-day supervision of hardware and software, and scheduling work throughput. This latter activity correspondingly received the highest level of sole professional responsibility in 63% of all Y01-25 practices. The most frequent incidence of sole technician responsibility (67%) was for file management, followed by day-to-day supervision of hardware and software (56%).

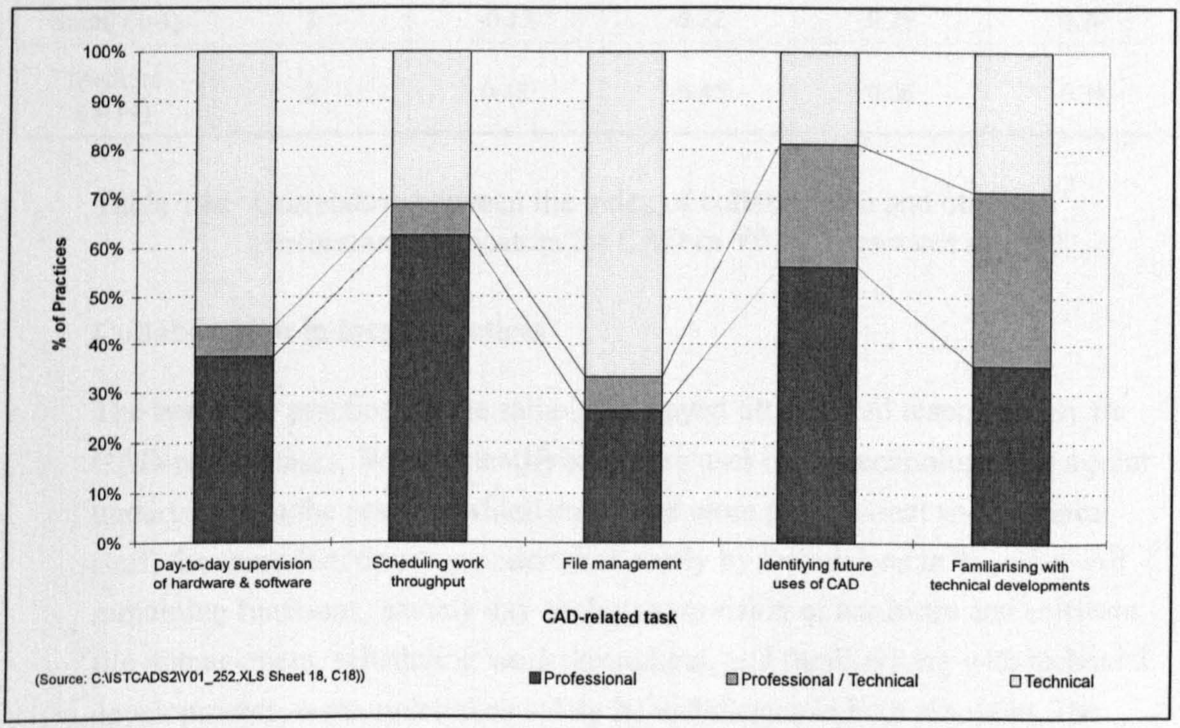


Chart 27 Distribution of CAD-related tasks in practices Y01-25 at 1995

Significance of distribution of CAD-related tasks in practices Y01-25

Relationships in the Y01-25 sample between collaboration of professional and technical staff for CAD-related tasks, achievement of benefits, the incidence of problems and success rates in resolving them, are summarised in Table 14d (p112). A higher level of collaboration between professional and technical staff to undertake CAD-related tasks was found to correlate variously with less problematic experiences of CAD. A positive coefficient of 0.45 linked the level of collaboration with trouble-free operations from the outset and the ability to solve problems which had occurred. A coefficient of -0.43 was found between collaborative working practices and the current incidence of problems with CAD. These relationships may in combination have explained the substantially reduced correlation of 0.28 between the index of collaboration and subsequent solution rates. In other words, those problems respondents were currently experiencing may have been the more resilient survivors of previous successful action.

Size of practice (NA staff)	Mean index of collaboration (Range 0-6)	Correlation with index of collaboration			
		Index of benefits	Index of problems	Solution rate	Problems never experienced / Problems solved
All	2.24	0.18	-0.43	0.28	0.45
Small (1-4)	3	-0.13	-0.22	0.29	0.34
Medium (5-14)	2	0.48	-0.45	0.06	0.28

Table 14d Correlation between the index of collaboration and other performance indicators for CAD in Y01-25 practices at 1995

Collaboration in large practices

The two large practices in the sample displayed little shared responsibility for CAD-related tasks. Whilst identifying future uses of the technology was a joint undertaking in the practice which employed more professional and technical staff, the same function was undertaken solely by technicians in the other. All remaining functions, namely day-to-day supervision of hardware and software, file management, scheduling work throughput, and familiarising with technical developments, were undertaken solely by technicians in both practices. The implication was that larger practices required their CAD technicians to provide a more comprehensive service and offered remuneration and other benefits capable of attracting suitably experienced personnel for this role. Unfortunately, limited representation of large practices in the sample prevented calculating indices of collaboration, benefits and problems to clarify the effectiveness of their approach.

Collaboration in medium sized practices

The distribution of CAD-related tasks in medium sized practices is represented in Chart 28 (p113). With a mean index of collaboration of 2 from a potential 6 medium sized practices collaborated 11% less on CAD-related tasks than the sample as a whole. This component of the Y01-25 sample had, at 50%, the highest incidence of shared responsibility for familiarising with technical developments in CAD, a figure 25% higher than for the sample as a whole. By contrast, medium sized practices also displayed a marginally lower incidence of collaboration for identifying future uses of the technology. This distribution of responsibility resulted in a correspondingly higher incidence of sole technician responsibility for the same function than found for all of Y01-25 respondents. No shared responsibility was found for file management in medium sized practices. Instead this function was the sole responsibility of technicians for 67% of respondents, and performed alone by professional staff in the remainder. By contrast an even distribution was evident for day-to-day supervision of hardware and software which was undertaken solely by professional staff in one half of the group, and by technicians in the other. There was a marginally lower incidence of sole responsibility in medium sized practices for technicians in scheduling work throughput than for the sample as a whole.

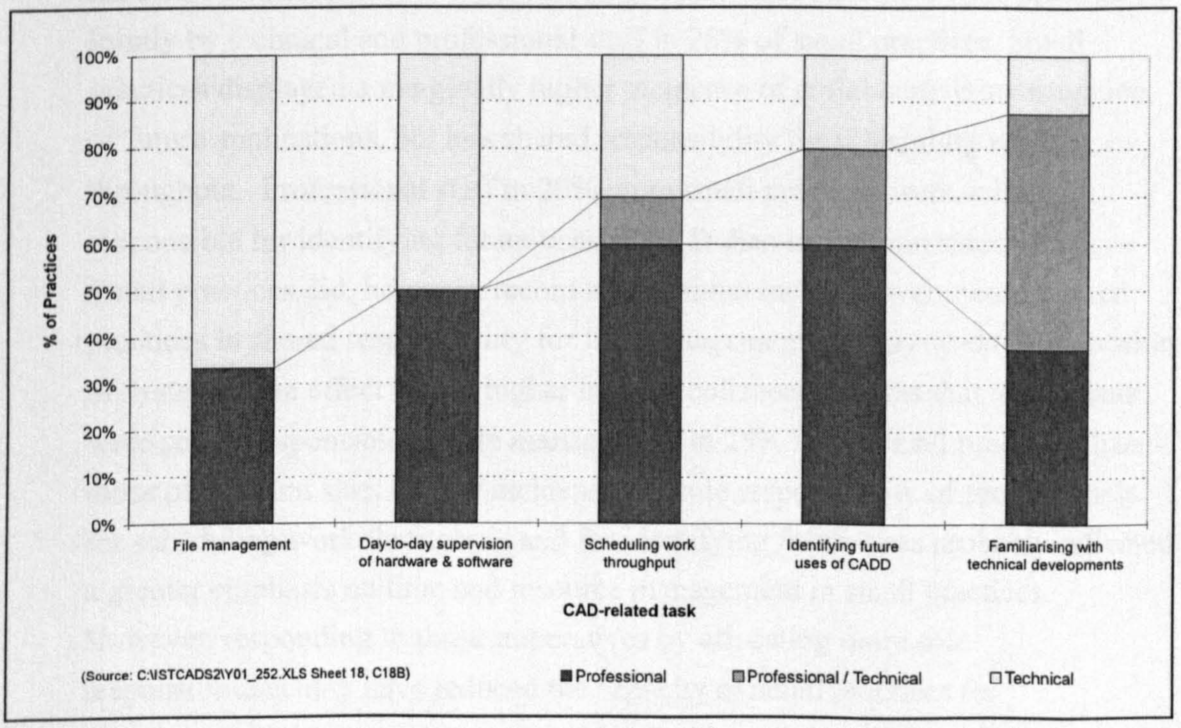


Chart 28 Distribution of CAD-related tasks in medium sized practices Y01-25 at 1995

Correlations between collaboration, benefits, problems and solution rates in medium sized practices are shown in Table 14d (p112). Although a correlation of -0.45 found between the index of collaboration and the index of problems was very similar to that for the whole sample, other coefficients differed. This section of the Y01-25 sample had a substantially higher correlation of 0.48 between the extent to which CAD functions were undertaken jointly and benefits derived from the technology. This may be attributable, at least in part, to more collaboration between professional and technical staff familiarising with technical developments. An appreciably lower coefficient of only 0.28 was identified between the index of collaboration and the extent to which problems were either never experienced or had already been solved. However, no significant correlation was found between the level of collaboration and solution rates for problems. Clarification of these two results would require further research.

Collaboration in small practices

The pattern of shared responsibility in small practices, summarised in Chart 29, page 115, differed variously from that found in practices of medium size. Where the latter had no incidence of shared responsibility for day-to-day supervision of hardware and software, or for file management, these functions were undertaken jointly by technical and professional staff in 25% of small practices. Small practices displayed a marginally higher incidence of collaborative investigation of future applications, but less shared responsibility for scheduling work throughput. Professional staff in 20% more small practices were solely responsible for identifying future uses of CAD than in medium sized practices. Small practices did, however, record a substantial increase over medium sized practices in shared responsibility for file management and day-to-day supervision of systems. The effect of this higher level of collaboration was that technicians were solely responsible for file management in 25% fewer small practices than those of medium size. Higher incidences of sole responsibility of professionals for scheduling work throughput and for identifying future uses probably reflected a greater emphasis on time and resource management in small practices. However, responding to those imperatives by allocating more sole responsibilities may have reduced the capacity of small practices for development initiatives. A relatively high incidence of problems making specific applications of CAD (Table 9, p72) was consistent with such a constraint. Advantages could be expected where understanding of opportunities and constraints in software systems enabled a closer relationship between development of CAD techniques and their application to authentic workload. Commercial benefits may have been more forthcoming, therefore, through closer involvement of technicians.

Table 14d (p112) shows that small practices, which had the highest mean index of collaboration (3), had a marginally negative correlation of -0.13 between their index of collaboration and their overall index of benefits from CAD. This result somewhat surprisingly suggests that benefits of CAD actually reduced for this size of practice as their staff worked together more extensively on CAD-related tasks.

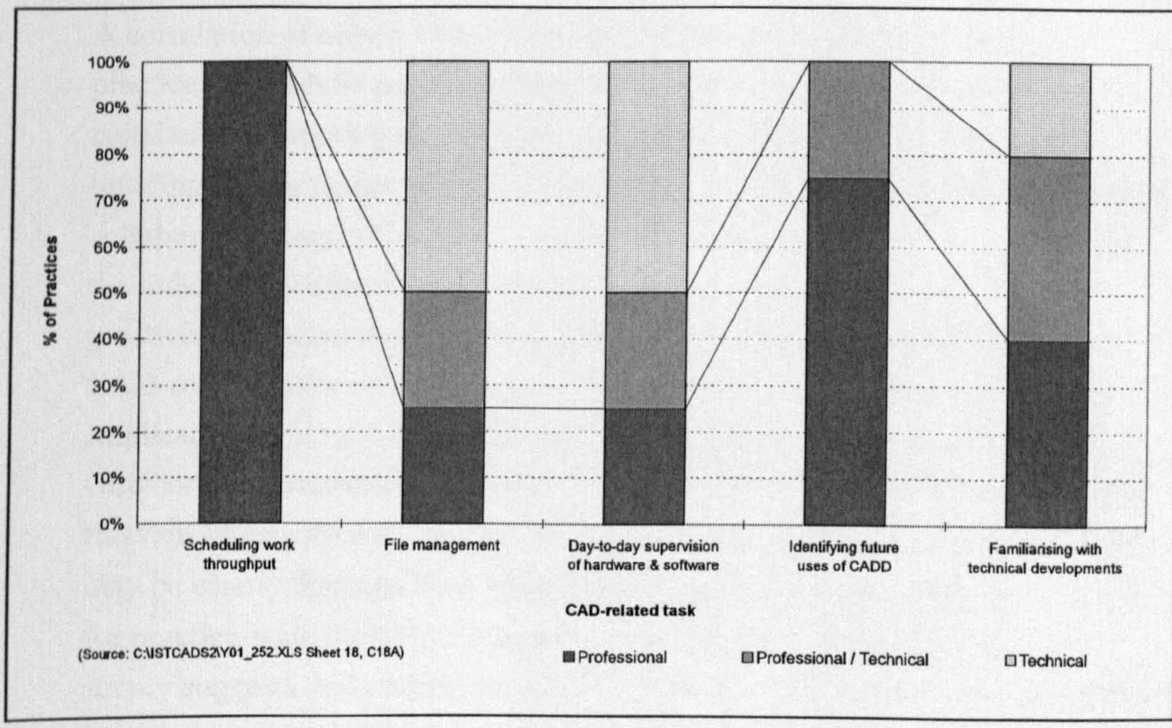


Chart 29 Distribution of CAD-related tasks in small practices Y01-25 at 1995

A coefficient of -0.22 was found when correlating the extent of collaboration with the overall index of problems, indicating a stronger association between collaborative working and a lower incidence of problems with the technology. However, by comparison with the coefficient of -0.45 for medium sized practices this correlation was considerably less apparent. A correlation of 0.29 was found for small practices between the index of collaboration and solution rates. The context for both results is set by the coefficient of 0.34 which linked the index of collaboration and the incidence of trouble-free experience of CAD, or problems already solved. The pattern of correlation between indices of collaboration and other indicators of performance for use of CAD can be seen to consequently reflect a number of factors. In the first instance it was consistent with the relatively high achievement by small practices in all categories of benefits from CAD. Secondly, the beneficial effects of collaboration in small practices were constrained by the extent of problems for which resourcing action was required, including initiatives to resolve incompatible hardware and software, as shown in Chart 12, page 71. Such constraints would remain relatively unaffected by the extent of collaborative working on CAD-related tasks investigated in the survey of practices.

Implications of collaborative practices for effective use of CAD

A correlation of only 0.18 between the level of collaboration for Y01-25 practices as a whole and their index of benefits from CAD appears to leave collaborative working as incidental to successful use of the technology in building surveying practice. However, closer analysis indicates that the results of collaboration vary with size of practice. The correlation of 0.48 found between the index of collaboration and the overall index of benefits in medium sized practices suggested that achieving effective collaboration to undertake CAD-related tasks was substantially more important in practices of this size. Implications from the marginally negative association between the index of collaboration and benefits from CAD in small practices should be drawn in the relevant organisational context. Although individual roles and associated duties may be clearly distinguished in small practices, an overriding imperative exists for practice-wide thinking, communication and associated action. The 1995 survey suggests that collaboration for the specific CAD-related tasks investigated is more important in small practices for reducing the incidence of problems with the technology and resolving those which do occur. With respect to the role of collaborative working, and scope for its beneficial development in large practices, there is a clear need for further research. Of the five CAD-related tasks considered in the survey, raising the level of collaboration in scheduling throughput of CAD-based work, familiarising with technical developments, and identifying future uses of CAD had most potental for contributing to an overall improvement in the performance of CAD in such practices.

In the context of advantages associated on pages 111-116 with collaborative working the need discussed in Sections 3.7 - 3.8.4 for more rigorous CAD strategies, (pp78-117), should not translate to a requirement for rigidly hierarchical management structures and procedures. Indeed, less hierarchical organisational structures have been acknowledged as more suited to achieving potential from CAD technology. Practices need CAD strategies that exploit the potential of collaborative working in CAD-related tasks for reducing problems and maximising benefits of the technology.

Whilst clear correlations were found between collaboration in CAD-related tasks and improved performance in terms of problems, and benefits to a lesser extent, the potential efficacy of such collaborative working should not be over-estimated. In particular, practices should acknowledge the limitations of collaborative working for overcoming resourcing and organisational constraints on performance of CAD. Those factors with major significance for deficiencies, and for which collaboration in CAD-related tasks has limited scope to overcome, include problematic specification and availability of hardware and software, characteristics of workload, and levels and frequencies of use of CAD by staff, particularly by professional staff.

It should also be acknowledged that the form and methods of collaborative working of optimal use in any given practice are likely to vary in response to the specific conditions of organisation, staffing, workload and use of CAD which prevail. Moreover, an optimal level of collaborative working may not occur in a practice because of lack of awareness of its significance for achieving effective use of CAD, or lack of willingness and ability to engage in relevant methods. Individual practices should therefore frame appropriate policies and practices, and undertake staff development in conjunction with adequate opportunities for staff to develop corresponding methods in response to their particular conditions.

3.9 Human performance deficiencies

Based upon the self-assessment by individual practices in response to the 1995 survey, and subsequent analysis of aggregated data in the research programme, a range of human performance deficiencies were found to have affected provision and use of CAD in the Y01-25 sample:

- Inadequate knowledge, understanding and skills for appraisal, specification, management and development of CAD.
- Fundamental lack of CAD knowledge, understanding and skills amongst potential end users of the technology.
- Sub-optimal application of CAD by existing users.
- Limited range of CAD capability.
- Loss of CAD-skilled staff.

Development of CAD in a practice was also found to contribute to human performance deficiencies through the need to use newly introduced software, either in support of the existing CAD system, or by its replacement with an alternative. Section 3.9 examines characteristics of the human performance deficiencies identified, and priorities expressed by practices for staff development. Discussion of the nature and adequacy of existing training interventions is followed by consideration of the need for alternatives.

3.9.1. Characteristics of human performance deficiencies and priorities for development

Inadequate knowledge, understanding and skills for appraisal, specification, management and development of CAD

Various implications were drawn on pages 78-117 for human performance deficiencies when considering the inadequacies of existing CAD strategies in the survey sample. A flawed knowledge base for appraising use of CAD was identified amongst the N01-25 practices which had retained manual methods between 1993-5 (pp79-84). Consideration of the need for alternative management action on pages 84-117 indicates that inadequate knowledge and skills were also substantial contributory factors in deficient aspects of CAD management and development for the CAD-using Y01-25 sample. These included monitoring and revising deficient working methods, allocating responsibilities for CAD-related tasks, and achieving suitably collaborative working methods (pp110-117). There was, however, no explicit acknowledgement from respondents that deficient knowledge and skills contributed to inadequate appraisal and specification of their CAD requirements or subsequent management and development of their systems. It is true that the survey did not directly seek to clarify human performance deficiencies other than those affecting practical application of software systems. Some respondents who identified problems with "Developing skills of professional and technical staff currently using the [CAD] system(s)" in question 5.3 (Appendix 2.1, Y01-25) may have been referring, therefore, to aspects other than development of practical ability. However, none took the opportunity in the questionnaire to qualify their response accordingly. The implication is that the question was interpreted, as the author intended, to mean capabilities for direct practical application of the technology. Another possibility is that although staff possessed adequate capabilities for management and development functions, they were too busy with other duties to apply their knowledge. Whilst the conditions in which practitioners necessarily operate (pp59-64) require that some allowance should be made for this possibility it is less plausible as a contributory factor in deficient CAD strategies than limited awareness of the issues involved, or their potential solutions. Evidence summarised in Chart 30 (p120) suggested improving profiles of previous CAD experience of amongst staff in that third of N01-25 practices which had installed the technology between 1993 and 1995. Although a third of building surveying professionals in these practices had little or no experience, a similar number had used the technology before to some extent, and the remaining third had made substantial previous use of CAD prior to its installation in the practice. 75% of the group had no building surveying technicians but, in those which did, all had used CAD before to some extent. Two thirds of the group had professional architectural staff, split evenly between those with some, and those with little or no, previous experience of the technology. A third had architectural technicians all with some CAD experience. Professional and technical engineering staff in the third of practices which employed them had made little or no prior use of CAD.

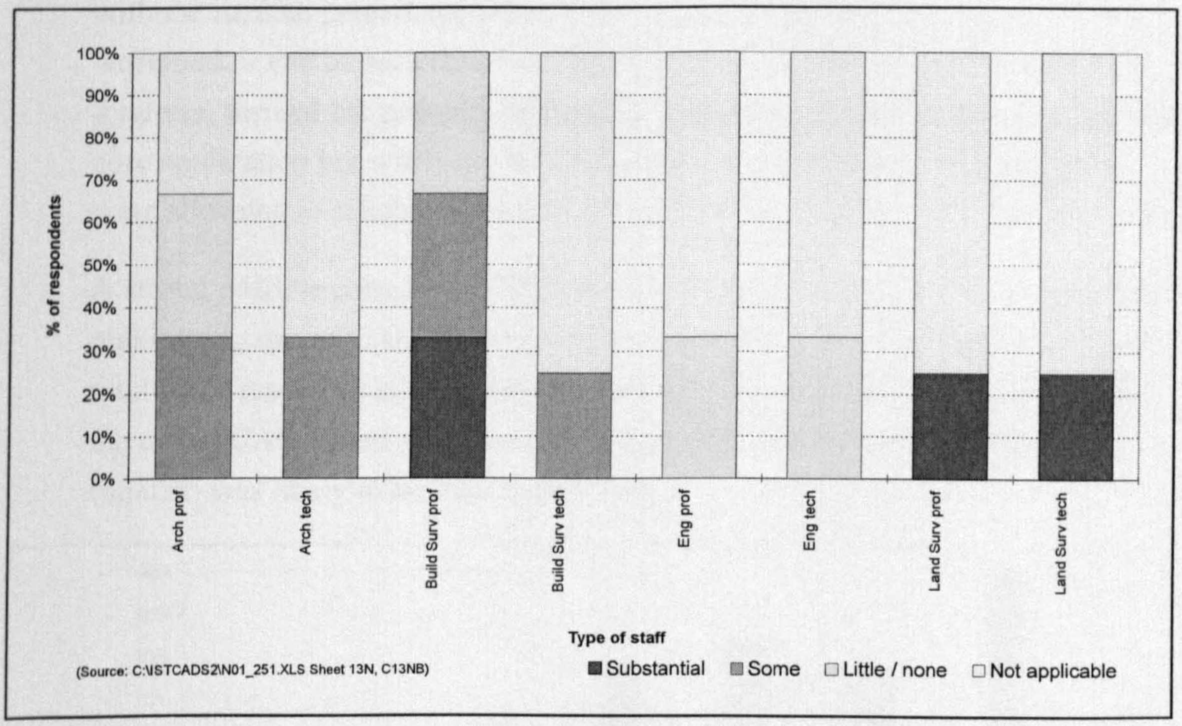


Chart 30 Previous experience of CAD in practices N01-25 with systems at 1995

However, 25% of the group employed land surveying professional and technicians, all with substantial experience of using CAD before its introduction to the practice. This profile indicated improved capabilities by comparison with others in the sample that were still without CAD at 1995, and that remained ill-equipped for in-house appraisal of the technology, as discussed on pages 78-83. In those practices, building surveying professional and technicians formed most of the workforce. 20% of the professionals had some experience of using CAD but the remainder had little or none. This section of the sample was without professional architectural staff but did have a very low incidence of architectural technicians with little or no practical experience of CAD. Such evidence of positive developments in the knowledge base must be moderated by acknowledgement on page 82 that at least some practices appear to have proceeded to install CAD with relatively little in-house capability for its objective appraisal or subsequent management and development.

Human performance constraints on practical application of CAD

An important factor in considering human performance constraints on practical application of CAD, as distinct from its appraisal, management and development, is the core set of applications made in the workplace. Chart 31 (p121) compares the total incidence of CAD use in the Y01-25 sample by commercial activity, with the median percentage use of CAD resources for the same components of workload. It can be seen that working drawings, accounting for 40% of median total use, formed the primary application. Measured building survey was the next core application but with only half the uptake. Slightly fewer CAD resources were allocated to scheme design which at 18% had the third highest level of use.

A strong positive correlation (0.83) was found between the number of practices making any use of CAD for a workplace activity[1] and the median proportion of total CAD resources allocated to that use. In other words the more widespread the use of CAD for an activity across the sample then the more heavily that function was likely to be used in an office.

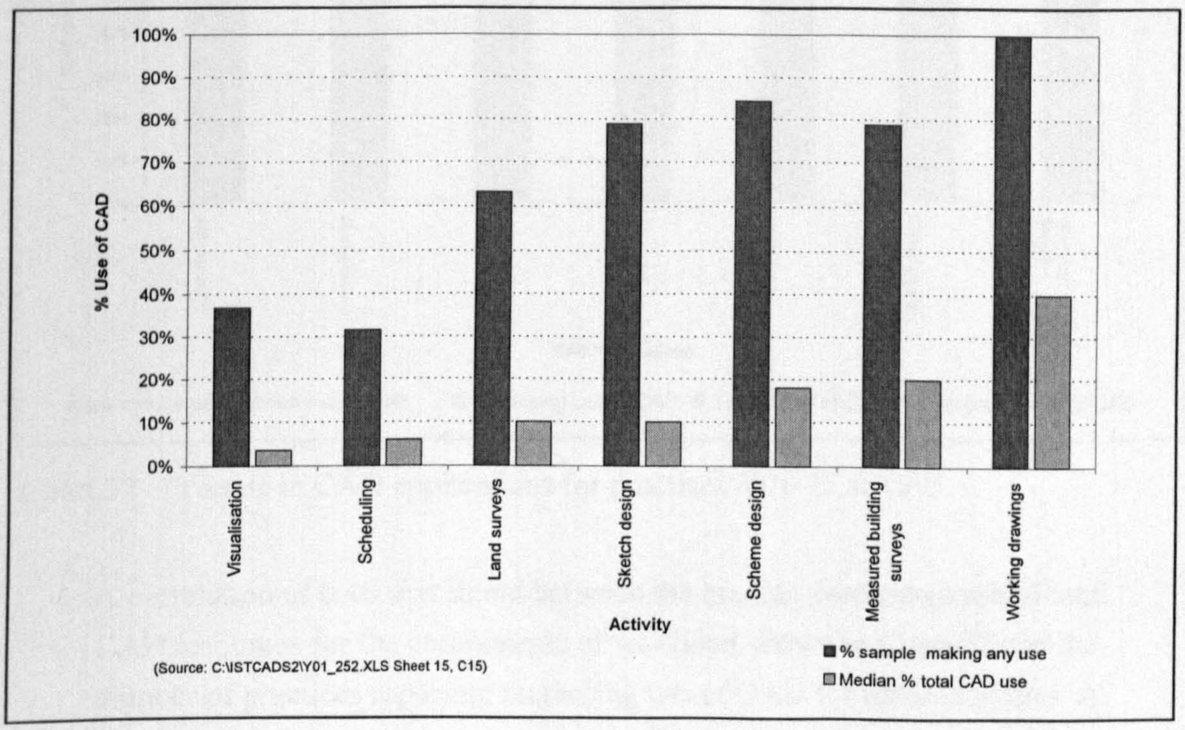


Chart 31 Median use of CAD resources by workplace activity in practices Y01-25 at 1995

Consideration should also be given to changing patterns of use. Trends in CAD applications for the Y01-25 sample, shown in Chart 32 (p122), indicate that the core applications identified above were increasing in a substantial proportion of practices. Application of CAD for working drawings was increasing in 50% of

1 Excluding facilities management for which there was no use of CAD, and record drawings for which only one practice quantified its use of CAD.

practices, whilst 47% and 44% of respondents recorded increasing use of CAD in measured building surveys and scheme design respectively. Only land surveying recorded a net reduction in application, although 33% of practices using CAD for this purpose reported an unchanged activity pattern, giving it also the highest level of static use.

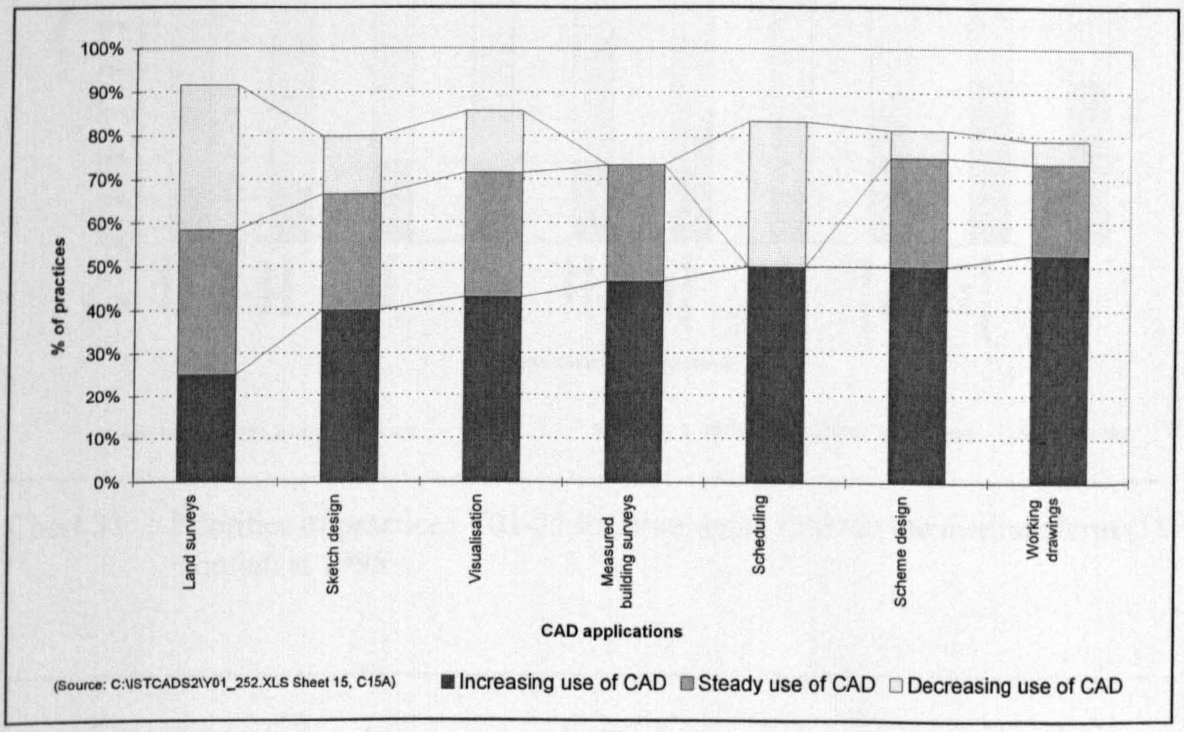


Chart 32 Trends in CAD applications for practices Y01-25 at 1995

A correlation of 0.46 was found between the median percentage use of total CAD resources for the components of workload shown in Chart 32 and the number of practices reporting increasing use of CAD for those activities. A corresponding negative correlation of -0.59 was found between median total use and practices reporting decreasing use of their systems for various activities. The observable trend in the sample was, therefore, for the more heavily used applications to command an increasing proportion of available CAD resources, and vice versa.

A third significant factor in considering human performance deficiencies is the range of priorities that practices may have for developing their CAD capabilities. Those identified by the Y01-25 sample at 1995 are summarised for the following 18 months (medium-term) in Chart 33 (p123), and for the following 3 years (long-term) in Chart 34, (p123).

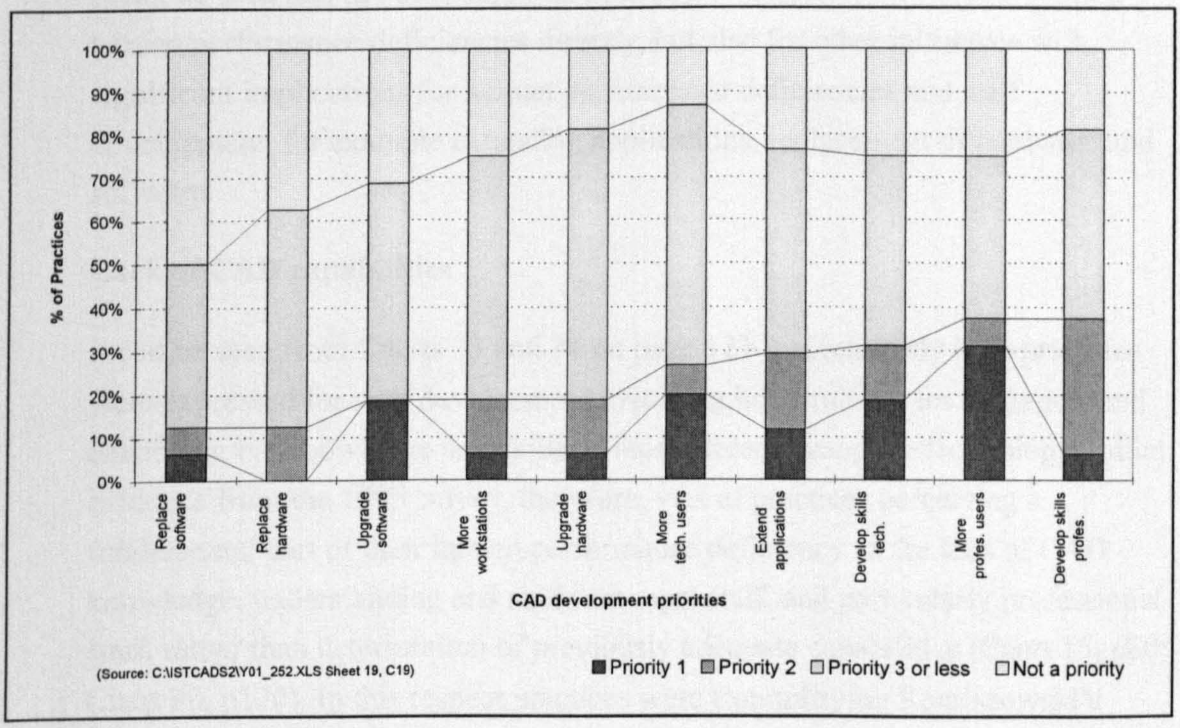


Chart 33 Priorities of practices Y01-25 for developing CAD in the medium term (18 months) at 1995

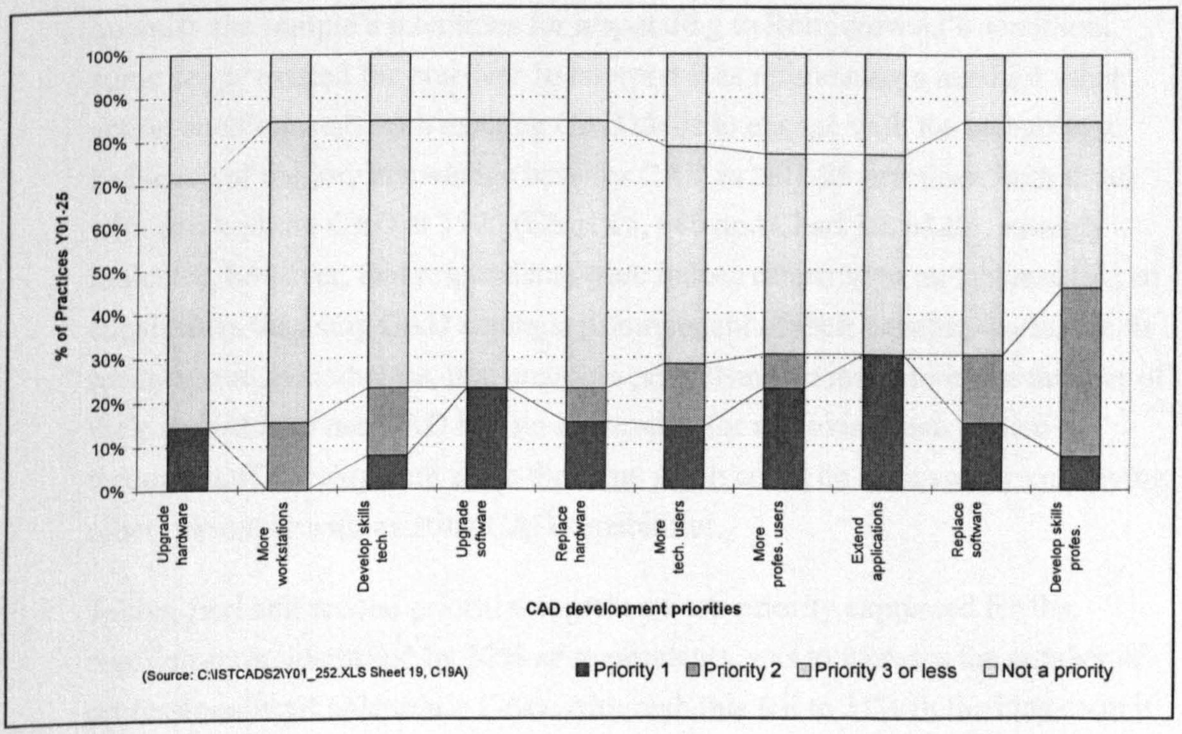


Chart 34 Priorities of practices Y01-25 for developing CAD in the long term (3 years) at 1995

It can be seen that in both cases practices expressed priorities for overcoming human performance deficiencies directly, but also for other initiatives with significant implications for human performance deficiencies and staff development, for example extending applications, replacement of hardware and software.

Lack of CAD capabilities

It can be seen from Charts 33 and 34 on page 123 that relatively high priorities were expressed for staff development involving both training for beginners and enhancing the knowledge and skills of those already using the technology. Initial evidence from the 1995 survey, therefore, was of practices perceiving a fundamental part of their human performance deficiency as the lack of CAD knowledge, understanding and skills amongst staff, and particularly professional staff, rather than deterioration of previously adequate capabilities (Chart 15, p80; Chart 30, p120). In this respect practices were exemplifying Romiszowski's (1984) case of "...never could perform adequately" and a prima facie need for instruction and learning, rather than for management or resource action.

Although question 5.3 in the 1995 survey (Appendix 2.1) was intended to quantify the sample's intentions for responding to Romiszowski's condition, some scope existed for practices to interpret it as referencing a need for other action enabling staff with existing CAD skills to engage with the technology. Evidence of the low knowledge base for CAD in N01-25 practices, both those with and without CAD at 1995 (Chart 15, p80 and Chart 30, p120), strongly indicates, however, that respondents were indeed referring to an inherent lack of capabilities for using CAD amongst a component of their existing workforce. It remains true, nonetheless, that practices prioritising an increase in the number of their staff able to use CAD had no imperative for achieving their objective through staff development since the same result could be achieved by employing other personnel with existing CAD capabilities.

Taking first and second priorities together, a top priority expressed for the medium-term, identified by 37% of respondents, was to increase the number of professional staff able to use CAD. Although this fell to 31% in the long-term it was still a second overall priority of the sample for that period. By comparison practices expressed less need to extend the number of technicians able to use CAD, recording it as their fifth priority for both periods. Although the percentage of practices registering this priority rose marginally from 27% in the medium-term to 29% in the long-term, the second figure included more rankings of second priority. The lower emphasis upon enabling this part of the workforce to use CAD may have reflected staffing structures in the responding practices, since fewer technicians in the workforce meant less scope for changing workloads or working methods. Extension of the user base for CAD implied by these priorities had the potential to accommodate intensification in use for the main applications of the technology discussed on pages 120-122. Staff already using CAD and experiencing this trend would sooner or later reach a limit to their productivity, thereby necessitating provision of additional capacity. However, those practices affected had no imperative for achieving their aspirations through development of existing staff. Some may subsequently have increased their number of professional staff able to use CAD by recruiting additional personnel with existing capabilities for using the technology. As with other aspects of a CAD strategy, the viability and relative merits of recruitment over training as a solution to human performance deficiencies would vary from practice to practice and need investigating locally.

Sub-optimal application of CAD by existing users

Improving efficiency as the predominant rationale for use of CAD fell from an initial 86% of Y01-25 practices at installation (Chart 8, p66) to 64% of the sample in 1995. Nevertheless it still substantially exceeded the next most widespread requirement (43%) for responding to the requirements of clients or collaborators. That all practices were able to improve their productivity through use the technology during at least part of the time, but only 44% could do so on a regular basis, indicated that application of CAD by existing users was sub-optimal for significant periods (Chart 9, p67). This assessment was reinforced by the high priorities placed by the Y01-25 sample upon developing the skills of those already using CAD in the workplace (Chart 34, p123). Professional staff were joint first priority in this respect over the medium-term, and shared top ranking with a need for increasing the number of professionals able to use the technology in the first instance. For the long term, developing the skills of professional staff became the single top priority. By comparison, technician staff were considered substantially less in need of development and attracted a medium term priority of three, falling to only sixth equal over the longer period.

The characteristic pattern of use for CAD in building surveying, discussed on pages 120-122, in which resources were increasingly concentrated upon a small number of core applications suggested potential for achieving significant productivity gains through even marginal improvement of techniques and processes. An important contributory reason why opportunities for more efficient methods through marginal enhancements might not have been exploited more effectively could be found in the low levels recorded for regular use of CAD, rather than in deficient instruction. Table 13, p100, shows that a median of only 14% of professional and technical staff used the technology daily, with another 29% using it at weekly or less frequent intervals. Personnel in the latter group could be expected to experience difficulty developing and sustaining efficient use of software simply through inadequate opportunities for reinforcement and practice. Strong opinions about inefficient use of CAD in building surveying were expressed by the principal of Horsham-based practice Y15 who was also Honorary Secretary of the UK Autodesk User Group, and whose practice had started using CAD in 1988:

> "There are many who claim to be conversant but who are painfully slow, don't write LISP routines or don't understand building construction."

Limited range of CAD capability

The fourth ranking medium-term (18 month) development priority for the Y01-25 sample was to extend the range of applications they made of CAD. This ranking was slightly lower than the priority given to developing the skills of technical staff currently using the software (Chart 33, p123). Although the proportion of practices involved rose only marginally, extension of CAD applications moved to second equal priority for the three year period (Chart 34, p123). As a long term aspiration this was second only to developing the CAD skills of professional staff already using the software, and displayed the highest number of first priorities rankings of all ten aspects for development, an increase from 40% to 100%.

The first main route to extending the range of applications was through application of core CAD functions to additional aspects of workload. The second option was to make more use of CAD functions with hitherto low uptake. However, an overall incidence of 53% for problems experienced by the sample when attempting to apply CAD to specific tasks, and a current incidence of 35% for such difficulties (Chart 10, p69; Table 9, p67) suggested contributory deficiencies in the capabilities of staff already using the technology. Indeed, such limitations probably contributed to the priority for developing CAD skills of existing users considered earlier. In the case of 3D modelling, 79% of the Y01-25 sample were equipped with relevant software and, given appropriate workload and in-house availability of corresponding knowledge and skills, theoretically able to benefit from its application. That only 25% of these practices regularly used their software for this purpose suggested that relatively little expertise existed in-house for such applications. Moreover, the knowledge and skills which did exist would tend to erode through irregular use and reinforcement.

Aspirations expressed by the sample for extending their range of uses for CAD were also in potential conflict with application trends. Broadening the application range by the second route, that is by making more use of CAD functions with hitherto low uptake, was at variance with the relative decline in use of software systems for components of workload showing a lower uptake in Chart 31 (p121). Such applications included scheduling and visualisation, as discussed on page 124. Additionally, availability of staff and workstations for such purposes was likely to become more restricted as a result of relative increases in use of CAD for the core applications discussed on pages 126-7. Assuming difficulties with access to CAD seats could be overcome, however, extending the user base for those core applications could help moderate human performance constraints on extending the application range. Reducing requirements for existing users of the technology to intensify routine applications could facilitate their scope for development work to extend the application range.

Loss of CAD-skilled staff

The most prevalent human performance problem at 1995, evident for half of the Y01-25 sample, was retention of CAD-skilled staff. It was also the least widely resolved constraint with only 11% of those practices affected having found solutions (Chart 10, p69; Table 9, p72). The incidence of difficulty varied with size of the practice and 60% of small practices had remained trouble free, compared to 45% of medium size. A high correlation of 0.87 between loss of CAD-skilled staff and difficulties experienced with applying the technology to specific tasks was evident across the sample. Successful action to improve retention of relevant personnel was also likely, therefore, to improve the practice's performance with targeted applications. The priorities of practices for increasing the number of staff able to use CAD, and for extending the range and effectiveness of those already using it, discussed in pages 124-125, suggested that practices were responding to the consequences of loss by developing the CAD capabilities of those personnel they were able to retain. The extent to which other action was taken to retain CAD-skilled staff, including job enlargement, enrichment, rotation and review of rewards, was not apparent from the survey results.

Consequences of developing CAD in the practice

Two broad scenarios for development of CAD in a practice, both apparent from Chart 34 on page 123, had potential for contributing to the human performance deficiencies discussed on pages 124-128. In the first instance a second equal priority for extending use of existing resources in the long-term might involve additional application of installed specialised extension software, or generate requirements to acquire additional applications. A need for various supplementary applications software may emerge in a practice through use of core CAD functions for routine work, or application of the technology for more specialised purposes, for example in measured survey. Increasing the level of regular use of CAD for core applications like production of working drawings, and to a lesser extent for measured survey and land survey, may have intensified the need for such support functions as CAD-based drawing management software. A second and more extreme source of change, also ranked as a second equal priority over the long-term, was for enhancing CAD capabilities by replacing existing software with a different system from the same supplier, or from an alternative source.

Derived demand for specialised extension software

At 1995 a considerable incidence was found of low utilisation for specialised software extensions, as discussed on pages 91-92. Potential explanations for the apparent disparity between availability and use of extension software include the possibility that such applications had been purchased unnecessarily at start up with CAD, possibly bundled with the main software system. In some cases the software may have been investigated and rejected as inadequate for the actual requirements of the practice. In other cases, although the level of use may have been very low, it was potentially at a commercially optimal level. In such circumstances existing skills may have been adequate for the required level of use and practices had no need for additional training. Given priorities expressed by practices for extending their range of applications, and for developing the CAD capabilities of their staff (Charts 33 and 34, p123), it is reasonable to assume, however, that in other cases a skills gap existed for specialised add-on software. Practices with relevant extensions to their base CAD software might, therefore, achieve worthwhile efficiency gains through staff development to enable more use of available functions. In these conditions the 23% of Y01-25 practices with provision for extending their CAD systems with drawing management software, but who were not using these capabilities, may have subsequently required instruction for their staff to develop relevant capabilities. Similarly, practices without software for this purpose may have needed to acquire it and undertake relevant staff development for its use. In yet other cases there may also have been hardware issues to resolve in order to realise such gains, for example conflicting demands on machine time and the absence or inadequacy of network provision. The extent to which available specialised applications were inadequate for the requirements of actual workload, or adversely affected by human performance, resource or management deficiencies, would vary from practice to practice. The significance and nature of remedial action, including staff development, would vary accordingly. The potential training implications of underutilised support functions, including drawing management software, were varied and needed clarification on a practice-by-practice basis (Chart 15, p80).

Replacement of core software systems

The second and more extreme scenario for development was highly likely to intensify human performance deficiencies. Although ranking only ninth equal priority in the medium-term the requirement to replace existing CAD software system(s) rose to second equal priority for the three year period. Priorities expressed for replacing core CAD software systems potentially rendered the CAD skills of existing users of the technology wholly or partially obsolete, and carried an implied need for staff development. Effective remedial action would require thorough review of existing application methods and opportunities for exploiting relevant capabilities of the replacement software. In this scenario it would be necessary to consider the extent to which the human performance constraints discussed on pages 124-128 might be accentuated and the prospects for, and consequences of, prompting a further cycle of negative responses to inadequate provision for CAD.

3.9.2 Existing training interventions and the need for alternatives

The 1995 survey showed that of the constraints on effective use of CAD in building survey practice, problems with training had at 72% the highest incidence in the Y01-25 sample (Chart 10, p69). Kenny and Reid (1988, p184) define a training intervention as "...any event which is deliberately planned by those responsible for training to assist learning to take place. It includes a wide range of activities from formal courses to structured work experiences..." Section 3.9.2 on pages 131-152 considers existing training interventions for CAD in UK building surveying practice, with an emphasis upon action to develop capabilities for practical application of software systems. Analysis begins with clarification of the timing and methods used for training in the Y01-25 sample. Problems with policies, resources and techniques to deliver existing interventions are then considered in relation to the inadequacies of CAD strategies discussed on pages 78-117. Implications are then drawn on the need for alternative action.

Timing of training

The 1995 survey results clarified the distribution of training interventions for CAD by building surveying practices. Results allowed comparisons between small and medium sized practices in the Y01-25 sample, specifically between their provision for professional and technical staff. Various similarities and differences were apparent.

To varying extents small and medium sized practices both provided training for their staff to use CAD during the three relevant periods, namely prior to acquisition of their CAD systems, concurrently with system acquisition, and subsequent to installation of hardware and software. Charts 35 and 36 (p132) show that in all but one period the sample displayed a greater tendency for training their technicians to use CAD than for similar preparation of their professional staff. The exception was a complete absence of pre-acquisition training for technicians in small practices (Chart 36). By comparison 44% of medium sized practices reported training their technicians prior to acquiring their CAD software. This historic focus on training for technicians was consistent with subsequently expressed priorities (Charts 33 and 34, p123) of respondents for increasing the use of CAD by professional staff.

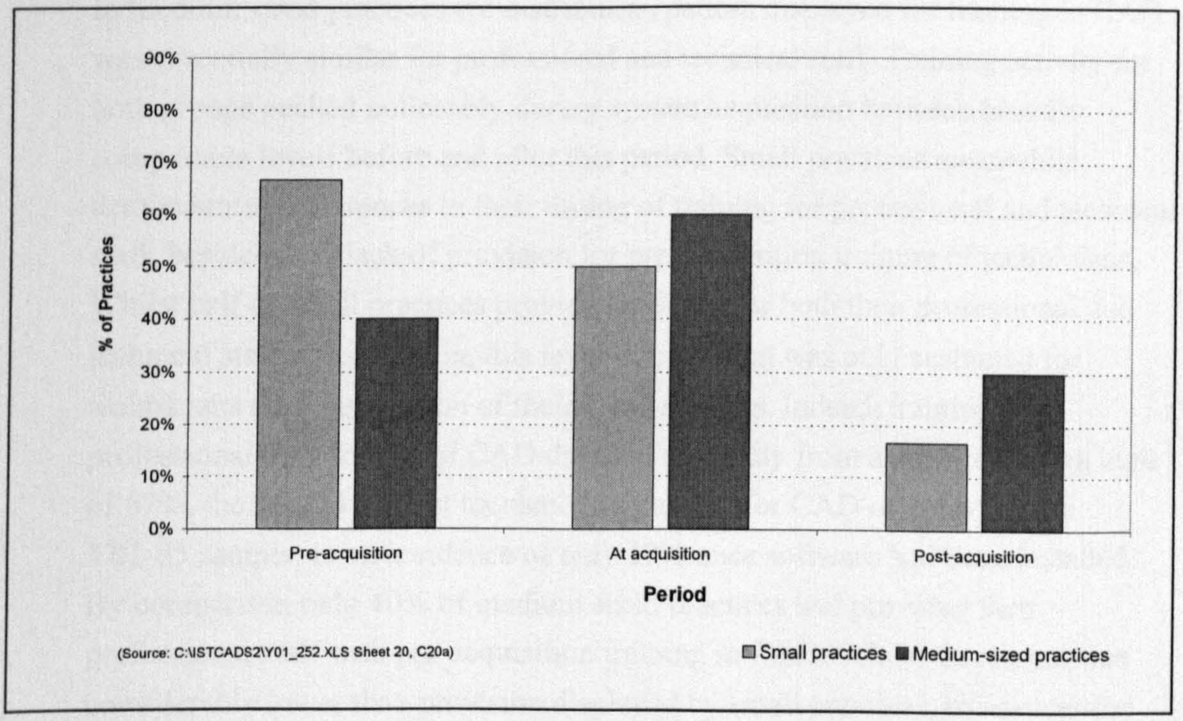


Chart 35 Timing of training for use of CAD by professional staff in small and medium sized practices Y01-25

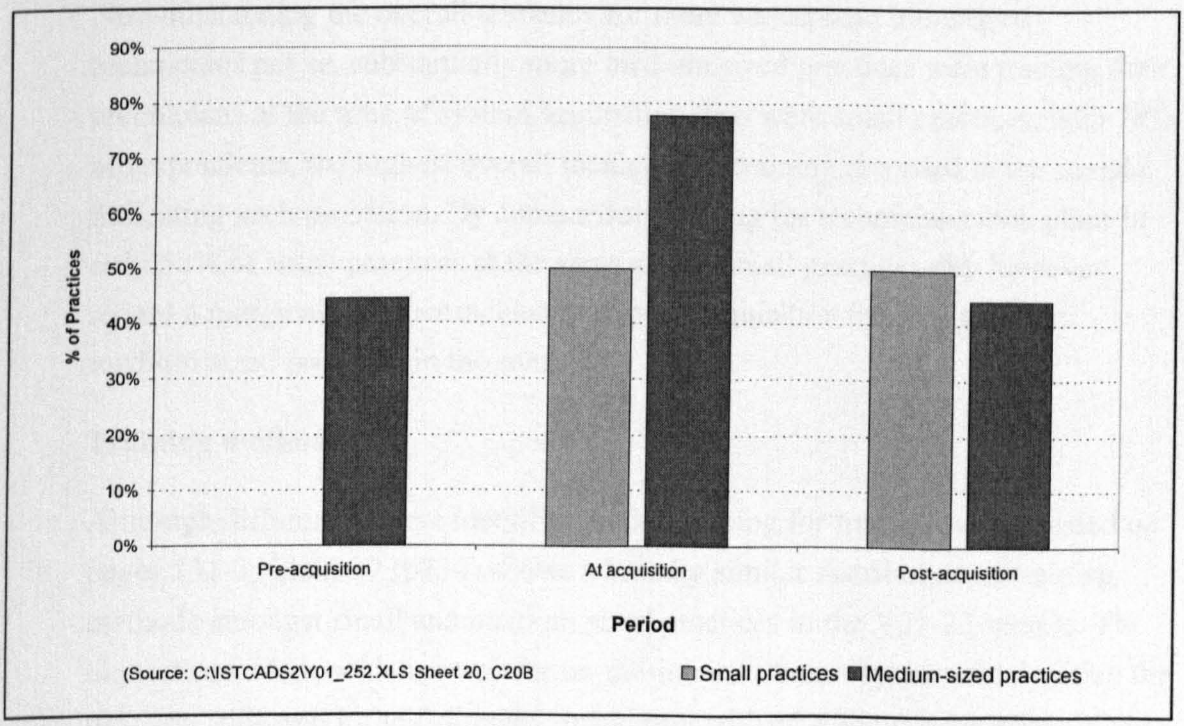


Chart 36 Timing of training for use of CAD by technical staff in small and medium sized practices Y01-25

In medium sized practices the distribution pattern displayed for training in CAD was essentially similar for professional and technical staff. Training activity for both groups peaked noticeably during system acquisition between broadly comparable levels before and after this period. Small practices meanwhile demonstrated differences in their timing of training for professional and technical staff, besides their lack of provision for pre-acquisition training of technicians. Whilst half of small practices provided training for both their professional and technical staff at acquisition, this level of provision was only sustained for technicians after installation of their CAD systems. Indeed, training of professional staff for use of CAD dropped markedly from a pre-acquisition high of 67%, the second highest incidence of training for CAD recorded by the Y01-25 sample, to an incidence of only 17% once software had been installed. By comparison only 40% of medium sized practices had provided their professional staff with pre-acquisition training in CAD. Whilst this figure was considerably lower than provision displayed by small practices, incidences for training professional staff of 60% at acquisition and 30% post-acquisition, were both higher in medium sized practices.

Notwithstanding the overall tendency for more widespread training of technicians per se, substantially more medium sized practices were training their technicians at the time of system acquisition than were small practices, with 78% of respondents, the highest overall incidence of training recorded in the sample, indicating such provision. By comparison training for technicians took place in only 50% of small practices at the same stage. Small practices did, however, record a marginally higher incidence of post-acquisition training than the medium sized practices in the sample.

Training methods

Although differences were identified in their timing for training, as discussed on pages 131-3, Chart 37 (p134) shows a broadly similar distribution of training methods amongst small and medium sized practices in the Y01-25 sample. The highest recorded incidence was for on-the-job instruction by personnel within the practice, followed by self-directed instruction with or without purpose-designed materials. Of these methods, on-the-job instruction was more prevalent in medium sized practices (78%) whilst marginally more small practices (67%) used self-directed instruction. Training courses run within the practice by an external agency, and those requiring attendance at an educational establishment, were each used by half of small practices. By comparison, marginally more medium sized practices (56%) used external providers to run in-house courses, but a third lower incidence (33%) occurred of sending staff for training to educational establishments. One evident common approach was that neither group sent staff for CAD training to commercial providers at their premises. The most obvious distinction between the two sizes of practice was the incidence of training courses run in-house by their own personnel. 44% of medium sized practices used this method compared to only 17% of small practices.

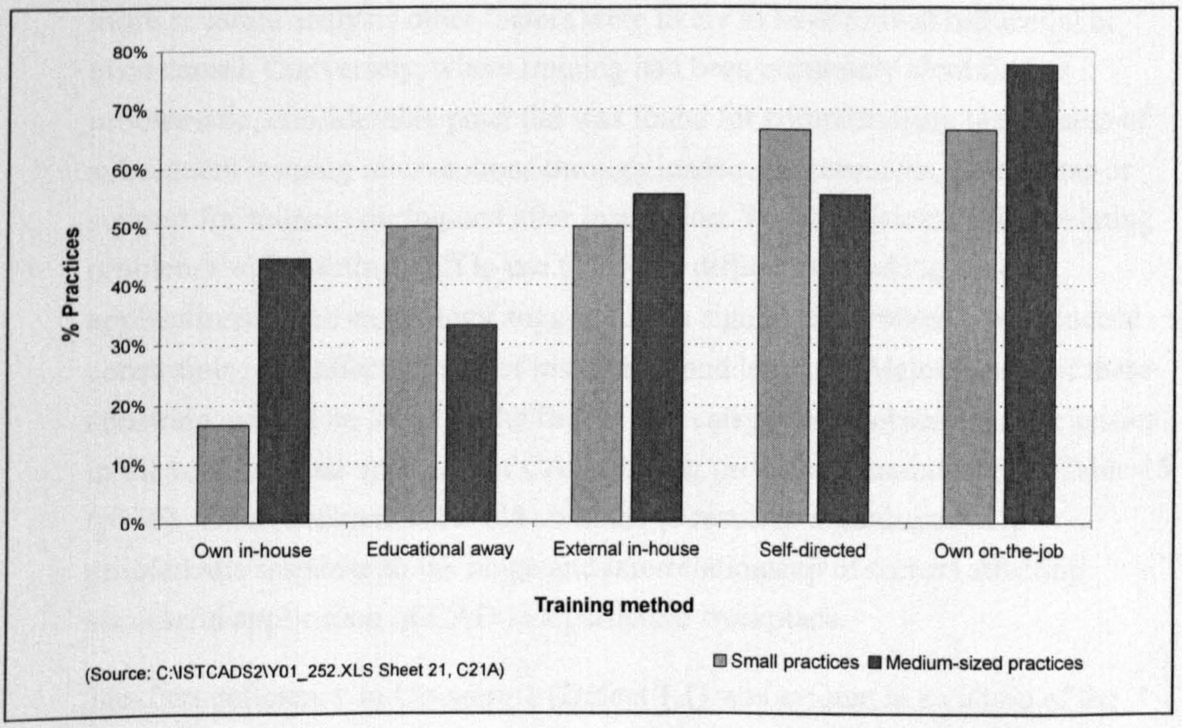


Chart 37 Methods used by small and medium sized practices Y01-25 for training staff in use of CAD

Problems with training for CAD

Overall 50% of the Y01-25 sample acknowledged their unsolved problems with training for CAD at 1995 (Chart 10, p69). The success rates for small and medium-sized practices in resolving such problems were low at 33% and 25% respectively. These compared to rates of 50% and 43% respectively for resolving problems with availability of CAD skilled staff (Table 9, p72). Consideration of the survey data, observation of training activities for CAD, and discussion with practices and other relevant agencies led to explanation of these difficulties with training in terms of three categories of inadequacies discussed on pages 135-148:

- Conflicting perceptions of the significance of training (Cause 1).

- Policies and provision for staff development (Cause 2).
- Methods used for training (Cause 3).

Conflicting perceptions of the significance of training

The consequences of constrained analysis, resourcing and management of CAD in building surveying practice were discussed on pages 78-117. In that context difficulties achieving effective use of the technology may have been erroneously attributed by practices to problems with human performance and training. In a more accurate analysis other factors were likely to have proved influential or even causal. Conversely, where training had been accurately identified as problematic, considerable potential was found for compromising the success of subsequent training interventions through inadequate resources, procedures or support for trainees during and after instruction. The coefficient of 0.83 relating problems with training staff to use CAD and difficulties making specific applications of the technology suggested that significant problems were indeed constraining the effectiveness of instruction and learning. Major causes of these constraints could be found in the first of two categories of observed deficiencies in the conventional approach of CAD training providers, summarised in Table 15 (p136). These deficiencies could combine to result in a fundamentally problematic response to the range and interrelationship of factors affecting successful application of CAD in a particular workplace.

The first deficiency in Category 1 (Defect 1.1) was evident in a culture of the CAD insider which prevailed amongst those designing and delivering training. The resulting tendency was for focusing attention upon technical knowledge of software, and the ability to execute complex procedures, in precedence to concern for associated commercial utility. Commensurately less concern was apparent for identifying and responding to specific requirements of individual workplaces. In the case of AutoCAD authorised training centres this tendency was endorsed by corporate policy which prevented them supplying CAD software. Their involvement with the strategies of their clients for implementing the technology were extensively limited as a result. Restricting their role in this way also resulted in a second Category 1 deficiency (Defect 1.2) in which an inherent tendency to emphasise the benefits of instruction was heightened regardless of other deficiencies, including constrained availability of hardware, software and staff for practice and reinforcement.

Deficiencies		
Category	Defects	
1. Inadequate response to the range and interrelationship of factors affecting successful application of CAD in a specific workplace.	1.1	Culture of the CAD insider with emphasis on technicalities of hardware and software rather than utility of technology to practitioners.
	1.2	Tendency to emphasise training solutions regardless of other deficiencies in the use of CAD.
	1.3	Tendency for training to be an extension of marketing.
	1.4	Animosity and rivalry between authorised hardware and software (AutoCAD) dealers and trainers to secure training business.
	1.5	Conflict between the imperatives of commercial provision of training for CAD and the methodologies required to research alternative instructional models and methods.

Table 15 Category 1 deficiencies in the conventional methods of CAD training providers : Inadequate scope

Whilst training centres were prevented from selling CAD software, Autodesk did allow authorised software dealers to provide training services. Resulting competition between different categories of suppliers in Autodesk's virtual corporation led to mutual animosity. Evidence was found of software dealers attempting to deter inquiries for training by removing contact information for training centres from the documentation supplied with software systems. Poor relations deteriorated further when Autodesk required its AEC training centres to test and report confidentially on the training competence of newly authorised software dealers. Unhelpful commercial rivalries to serve a common user base that originated from these various organisational difficulties resulted in Defect 1.4 to the detriment of clients. The likelihood of achieving satisfactory provision and use of CAD in any particular case was correspondingly reduced.

For Autodesk, at least, training was observably a strand in its marketing strategy for CAD software. An example of this perception occurred early in the research programme when the product manager for the AutoCAD Architectural, Engineering and Construction (AEC) extension required those centres authorised as trainers for the software to become significantly more active in selling AEC. To this end the company obliged them to participate competitively, and at significant cost, in the 1992 CADCAM trade fair at the Birmingham National

Exhibition Centre. Other aspects of marketing were less overt, as exemplified in the Autodesk (1992a) submission criteria for the AutoCAD AEC modular training programme. This documentation served to regulate the content and structure of training by requiring compliance with a detailed published syllabus. Controls of this type over the content of instruction tended to encourage trainees to develop overly favourable perceptions of utility in the software. They also functioned to moderate understanding of deficiencies in the system and encourage acceptance of a need to regularly purchase updates as the norm (Defect 1.3).

An overarching defect in Category 1 concerned potential conflict between the imperatives of commercial provision of CAD training, and the methodologies required for researching and developing alternative instructional models and methods (Defect 1.5). This difficulty can also be illustrated by reference to AutoCAD authorised training centres. Achieving authorised status was generally accepted by the software company and training providers to substantially determine demand for the CAD training services of the recipient organisation. Autodesk's quality assurance procedures, however, required production and use of instructional material in response to the company's increasingly prescriptive and detailed syllabi. The costs and overheads involved in doing so were predominantly borne by small organisations with limited resources and turnover, typically income generating units in further and higher education establishments. Such providers consequently had little choice but to concentrate on profiting from their authorised status and associated expenditure. As a frequent result, scope for developing alternative approaches to training was considerably reduced. In this way Autodesk's regulatory policies initiated and sustained an uneasy relationship between the world's leading supplier of CAD software and a spatially dispersed collection of local suppliers for training users of its products. An incongruous contrast existed, therefore, between restrictive policies for training, and the open system architecture through which third party developers were encouraged to research and develop extensions of the base AutoCAD package for specialist requirements.

Inadequate policies and provision for staff development

As reported on page 84, Y01-25 respondents and N01-25 practices with CAD had installed their systems largely regardless of staff preferences (Chart 14, p79). This approach had consequent potential for prompting negative attitudes towards associated policies and practices, including staff development. The possibility of negative reactions could be expected to increase where diversity and duplication of CAD hardware and software followed dissatisfaction with earlier provision (Chart 11, p71).

The low uptake of training after acquisition of CAD hardware and software, particularly for professional staff in small and medium sized practices, reported on pages 131-133, could be expected to limit opportunities for resolving human performance constraints on developing the CAD strategy for a practice. Such constraints would also adversely affect individual or collective applications of the technology within a CAD strategy.

One practice with considerable experience of the technology, however, strongly expressed a view that policies for developing the capabilities of professional staff to use CAD directly were fundamentally misconceived. Horsham-based practice Y15 had started using CAD in 1988 and its principal had been Honorary Secretary of the UK Autodesk User Group since 1993. In response to Question 7 in the 1995 survey, requesting additional comments on use of CAD in the practice or building surveying generally, he was unequivocal about the utility of training professional staff for direct use of the technology:

> "It is uneconomic to train professional staff in CAD, those who do - do so in their spare time - We can never begin to compete in productivity to a highly regarded and highly paid technician who spends 37.5 hours a week at it instead of say 10. Paper plots are produced and checked by professional staff. Ultimately the software will no doubt develop to the extent that professional staff do draw but this is perhaps 10 years off."

Notably, however, the fundamental issue in this argument was not the viability of CAD training for professional staff per se, but constraints on subsequent reinforcement and practice through which to develop proficiency. This appraisal was supported by a correlation of 0.55 found in small practices between the percentage of professional staff using CAD daily and the index of benefits from CAD. This coefficient suggested that the effectiveness of training is likely to be reduced by constrained opportunities for staff to reinforce and practice the content of training events.

In those Y01-25 practices which nonetheless, were training professional staff for CAD the emphasis in selection of methods, summarised in Table 16 (Chart 35, p132), indicated a marked sensitivity to the costs of provision. This concern with costs potentially rendered staff development policies and methods inadequate. On-the-job training by their own personnel, used by 67% of small practices and 78% of medium sized practices, was the method with highest uptake. On-the-job training need have no other resource implications than the marginal opportunity costs of staff and computer time for instruction and learning during normal fee-earning application of CAD to components of workload. Arguably therefore it also coincided with the lowest additional outgoings. Staff development by this method was normally ad hoc with little of the planning, design or other preparatory activity associated with in-house delivery of training courses by staff for the benefit of their colleagues. Significantly the sample made substantially less use of the latter method recording an uptake of 44% amongst medium sized practices and only 17% in small ones.

Size of practice	Highest	Second highest
Small (1-4)	By own personnel on the job (67%); Self-directed instruction (67%) (1=)	-
Medium (5-14)	By own personnel on the job (78%)	Self-directed instruction (56%) In-house by external personnel (56%) (1=)
Large (15+)	By own personnel on the job (100%); Self-directed instruction (100%) (1=)	-

Table 16 CAD training methods with the highest incidence for practices in the Y01-25 sample

The timing of training indicated in Charts 35 and 36 (p132), and a higher incidence of training courses run within the practice by an external agency, as distinct from in-house staff (Chart 37, p134) is significant. Such provision is likely to have involved the limited training commonly included, or offered at preferential rates, with purchase of new CAD software. Similarly the uptake for training courses requiring attendance at an educational establishment (50% in small, and 33% in medium-sized practices) would typically also have offered practices various cost advantages. Historically colleges of further education, and more recently some universities, have offered alternative modes of training courses for CAD. Amongst these the City and Guilds schemes have been provided as a series of evening classes at relatively low cost. Less commonly they have also been available for intensive block study, but usually at higher rates. Use of evening classes for staff development achieves financial savings for a practice and avoids direct loss of productivity during normal working hours. Educational establishments also include instruction in CAD as components within courses for professional qualifications and some respondents may have been identifying training by this route. Although such provision usually incurs the costs of day-release, instruction in use of CAD is rarely an itemised component. Moreover, where staff become productive users of the technology, CAD capabilities may be delivered as one in a range of benefits for the practice. Price sensitivity as a significant factor in choice of training methods was reinforced by the sample's total avoidance of provision requiring attendance at a commercial establishment. Whilst some commercial providers are flexible in timing their delivery, and may run weekend courses, the norm is for attendance during office hours, and at substantially higher fees than those charged by educational establishments. Practices must, therefore, forfeit the services of those staff absent for training, incur the relatively substantial costs of instruction, and possibly also accept the additional expense of travel and subsistence.

In various ways, therefore, price sensitivity of practices to training for CAD tended to emphasise low cost solutions involving the more ad hoc and less structured methods of on-the-job training, and self-directed instruction. More structured methods were likely to be limited to extensively generalised instruction through introductory training from suppliers in association with system acquisition, and attendance at educational establishments. By contrast, those methods more responsive to particular requirements with most potential for individualised instruction, that is in-house training courses from their own personnel or external providers, were both underutilised. In combination with the problematic conditions of staff availability discussed on pages 104-105 these factors extensively constrain staff development to use the technology and retain relevant CAD knowledge and skills. They contribute substantially to explaining why 72% of all practices in the Y01-25 sample had experienced problems with training for CAD.

Inadequate training methods

The 1995 survey showed that up to 28% of respondents (Chart 10, p69) had achieved at least adequate success with self-instruction or on-the-job learning as the two main methods by which building surveying practices attempted to develop practical capabilities with CAD systems (Chart 37, p134). Nevertheless it is also necessary to acknowledge that both methods display inherent deficiencies. Effective self-instruction is largely dependent upon suitable characteristics and traits of the learner, including enthusiasm and persistence in the tasks involved. Where such learning is attempted without purpose-devised resources then he or she may need to function successfully in the role of instructional designer to identify appropriate learning material and then regulate and monitor its use. These functions are variously problematic to perform and adequately integrate, as discussed on pages 153-381. Reliance upon self-instruction for learning how to use CAD software tends also to result in self-selection for its subsequent application in the practice. This may lead to ad hoc and uncoordinated deployment of the technology rather than in accordance with an explicit and generally understood management and development strategy. Some practices may be fortunate and experience a virtuous circle in which appropriate abilities are developed in response to creative analysis of problems and requirements. Successful self-starters elsewhere may become frustrated with the difficulties of achieving effective use of CAD in the workplace which enabled development of their abilities but persists with an inadequate strategy for implementing the technology. Over time such difficulties may contribute to their leaving the practice and benefiting a competitor.

Successful on-the-job learning, like self-directed instruction, depends extensively upon the personal characteristics of those involved, but places significant responsibility for the content and delivery of instruction upon staff other than the learner. Unless appropriate time, thought and effort are applied to this role, on-the-job learning may prove ineffective. The possibility exists, therefore, of training and associated support becoming unacceptably onerous for the personnel involved, resulting in a reduction of their own productivity, and contributing to reasons why CAD-skilled staff might leave a practice.

Training by external providers was the third main method by which the Y01-25 sample equipped its staff with CAD capabilities. Problems in the conventional methods of external providers of CAD training were apparent through combining analysis of sources from the literature search, and collating the knowledge base of generic problems with training and gaps in knowledge (Fig. 6, p38). Insights were also gained through discussion with personnel from representative agencies, and observing trainees undertaking commercial courses or students in undergraduate classes. Collated observations are summarised in Table 17 (p143). These defects are additional to inadequate responses in respect of the range and interrelationship of factors affecting successful application of CAD in a specific workplace discussed on pages 135-137 and summarised in Table 15, page 136.

In a simplistic analysis of requirements, building surveying practices needed more capacity for 2D drafting as their primary application and using AutoCAD as their principal software system (Chart 15, p80). Providers of CAD training tended to apply a correspondingly unsophisticated classification of training requirements by assigning trainees to either introductory, intermediate or advanced training courses (Defect 2.1, Table 17). Closer consideration of results from the 1995 survey reported on pages 120-128, however, showed actual requirements of practices for specific applications of 2D drafting using different versions of AutoCAD and a variety of other proprietary systems. Significant local considerations included whether trainees were professional or technical staff, and the extent of their existing CAD knowledge and ability. Moreover, their performance objectives would vary between practices and, similarly, the time acceptable for achieving productive application of the software. Whilst practices experienced problems making specific application of a range of CAD software systems and releases to different types and sizes of new build and refurbishment schemes, authorised providers were required by suppliers to concentrate upon delivering instruction with the current release of the software and emphasise new technical enhancements (Defect 2.3). The City and Guilds of London Institute, meanwhile, required uniform delivery of its training schemes with standardised content and data using the CAD software release prior to the current commercial version. In this context provision of individualised instruction was usually regarded as achievable only as an additional service and at higher cost.

Deficiencies	
Category	**Defects**
2. Inadequate methodologies for analysis, planning, design, production and delivery of instruction, assessment and associated resources.	2.1 Simplistic distinction between introductory, intermediate and advanced levels of training.
	2.2 Lack of explicit and rigorous methodologies for instructional design rarely perceived as a problem by training providers.
	2.3 Polarisation of CAD training between general methods with indicative content and elaboration of software technicalities with few authentic applications for the target population.
	2.4 Content based predominantly on new build schemes.
	2.5 Over-reliance on generic, paper-based instructional material pre-structured for longevity with a wide user base.
	2.6 Perception, reinforced by paper-based learning resources, of learning as a predominantly linear activity. Inadequate provision for rapid or independent progress.
	2.7 Inadequate provision in diagnostic assessment, instruction, reinforcement and practice for variations in previous experience and learning capabilities or other constraints.
	2.8 Inadequate relationship between the order of procedures for cost-effective application of CAD in the workplace, and the sequencing and progression of activities for developing corresponding understanding, knowledge and practical abilities.
	2.9 Presumption for automatic transfer of learning from pre-structured, generic, paper-based instructional resources to effective application in the workplace. Inadequate formative and summative assessment of the trainee's knowledge, understanding and practical ability.
	2.10 Inadequate provision, including constrained staff time, for reviewing the effectiveness of training. Instructional material remains little changed until rendered unusable either by: 1. Requirements of clients. or 2. Changes in the CAD software system requiring modification of data, procedures or formats.

Table 17 Category 2 deficiencies in the conventional methods of CAD training providers : Inadequate analysis, planning, design, production and delivery

In terms of its theoretical basis, Scandura (1983, p217) set the context for appraising conventional training for CAD with a highly critical assessment of the status of recent instructional theories:

> "Most current 'instructional theories'... consist largely of taxonomies and techniques... Designed to meet immediate practical ends and, therefore, tend to be highly discrete and peculiarly related to particular needs. In most cases, they only minimally satisfy the requirements of good theory: completeness, comprehensiveness, parsimony, precision and operationality."

Much provision for CAD training was more questionable since little directly relevant theory had been found in the literature search. Moreover, detailed discussion of taxonomies and techniques for analysis, planning, design and production of CAD training was also very scarce. Training providers rarely perceived the lack of explicit, rigorous theory for their instructional design activity as problematic. Indeed, some regarded the search for improved methods as an unnecessary distraction from the core business of generating fee income from training events. Others reacted defensively to implied criticism of their current practices (Defect 2.2). Such slight regard for theory would have been more justifiable if training practices were demonstrably better aligned with the requirements of client, and were achieving more effective results.

Concentration of CAD activity in the Y01-25 sample on a small number of core applications, as shown in Chart 38 (p145) potentially enabled training providers to achieve economies of scale by targeting applications with widespread currency. However, achieving the marginal improvements in application methods indicated on page 126 for securing productivity benefits from core applications required targeted instruction. Such training would enhance the knowledge and practical abilities of staff already using CAD, and align new users with production methods preferred in the practice. By contrast, training providers were more likely to benefit from instructional resources capable of use and reuse with the widest possible range of trainees, and consequently less suitable for such purposes. Reliance on generic, paper-based instructional material, pre-structured with content selected for the greatest longevity with the widest possible user base was consequently common practice. As a result training for the major CAD software systems predominantly involved new build rather than refurbishment schemes which formed a substantial component of workload for building surveying practices (Chart 4b, p62) (Defects 2.4, 2.5).

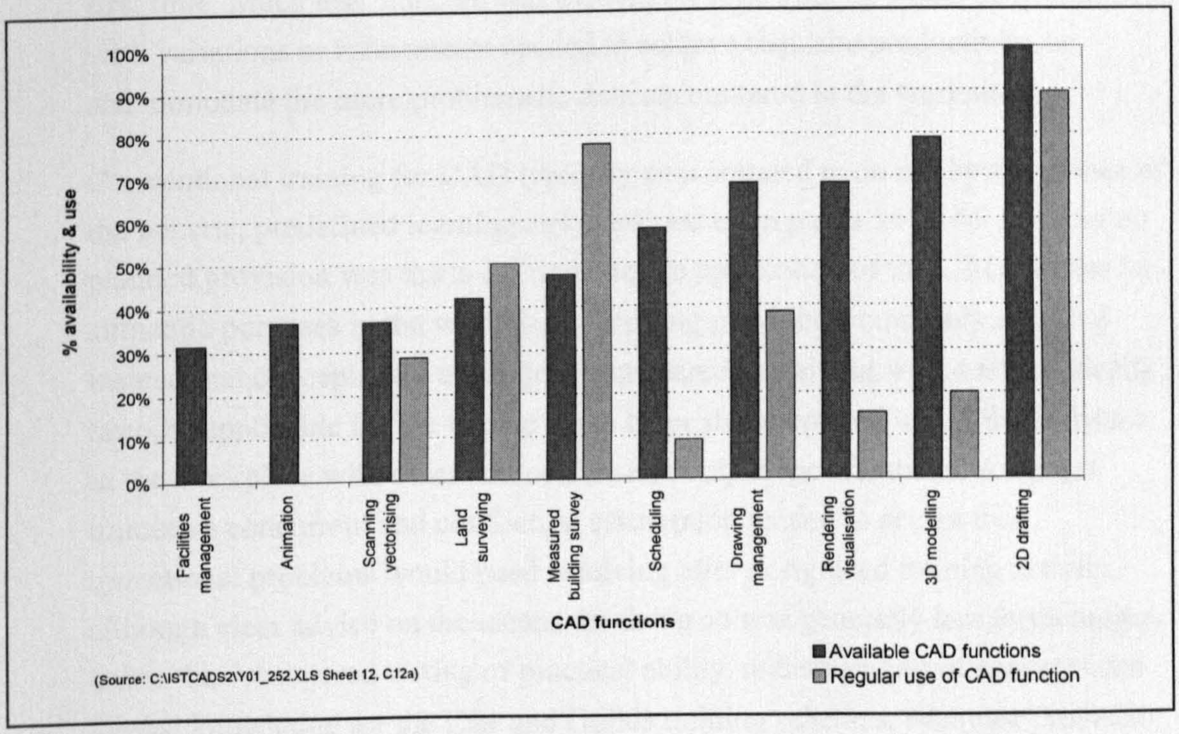


Chart 38 Availability and regular use of CAD functions by practices Y01-25 at 1995

Design, production and use of paper-based learning tasks tended, through the nature of the medium, to reinforce perception by the instructor and trainee of learning to use a CAD system as a predictable linear process. Adequate provision was rare for diagnostic assessment to test the readiness of a trainee for undertaking an exercise, or its components. Similarly, little provision was included for the trainee to make rapid progress through a designated worksheet as a result of relevant existing knowledge or accelerated learning (Defect 2.6). This latter characteristic was associated with a wider deficiency whereby training, subsequent reinforcement, and practice with CAD in the workplace tended to respond inadequately to variations in previous experience, learning capabilities, or the resourcing and organisational conditions which pertained (Defect 2.7).

Relationships between procedural sequences for cost-effective application of CAD in the workplace, and the order and progression of activities for developing corresponding understanding, knowledge and practical abilities of the trainee were rarely well developed (Defect 2.8). Instruction tended to concentrate upon activity sequences and data selected for ease of comprehension and implementation by trainees engaging with relevant aspects of the system for the first time. Much less concern was evident for following up initial demonstrations with variations or refinements needed to achieve requisite productivity, or accommodate the more problematic data encountered in the workplace.

Conventional training for CAD typically concentrated upon use by the trainee of the generic, predefined learning tasks referred to on pages 144-146. Little or no planned provision was made for transition to application of the CAD system for authentic purposes in the workplace. Training providers commonly assumed instead that concepts and techniques considered in training would automatically become applicable for the trainee when he or she attempted use of the software in the workplace with other source data and output specifications. Amongst trainees a concurrent and conflicting assumption tended to accept that transitional problems would need resolving after designated training activity, although clear advice on the means for doing so was generally less forthcoming. Other than structured testing of practical ability, understanding of concepts and factual knowledge for the City and Guilds training schemes, adequate provision was rarely made for formative and summative assessment of the trainee during and after training (Defect 2.9). Such omissions allowed instructors and trainees to accommodate the negative consequences of those deficiencies, discussed above by not confronting mismatches between the stated objectives and actual achievements of their training interventions.

Observation of training providers, and discussion of their methods, indicated a general disinclination and inadequate mechanisms for reviewing the effectiveness of training processes and resources. In combination with widespread constraints on staff time these deficiencies left instructional material largely unchanged until client requirements, or changes in the CAD software system, rendered documentation and associated data files unusable for training. The common tendency when changes became inevitable was to attempt preparation of replacements by reworking, or 'tweaking', existing material (Defect 2.10).

To varying extents the framework for the City and Guilds of London Institute (1993) scheme AEC in the Built Environment (4251-06), and the methodology selected by Autodesk's authoring group for its production, summarised in Fig. 12 (p147) demonstrated a substantial number of Category 1 defects (1.1, 1.3, 1.5, Table 15, p136). Problematic characteristics were also apparent from Category 2 (2.1-2.3, 2.5-2.9, Table 17, p143).

1. **Identify broad target audience of sufficient size to justify production of training course in financial terms. (Beginner, intermediate, advanced)**
2. **Analyse command and function set of the subject CAD software release and select aspects relevant to the target audience.**
3. **Identify 2D drawing(s) or 3D model(s), including re-use of data from existing training material, as content for commands and functions identified in Step 2, above.**
4. **Prepare step-by-step paper-based documentation and associated CAD files for use by instructors and trainees.**
5. **Test documentation for technical errors and amend as necessary.**
6. **Run self-contained on-site and off-site courses of pre-determined duration based on documentation produced in Steps 4-5.**

Fig.12 Common methodology for design and production of CAD training courses and associated resources

In the first instance sponsors and providers of potential CAD training identified a broad target population for the proposed provision. The essential consideration was that the identified population displayed sufficient size to justify organising delivery and developing training materials. In the case of City and Guilds Scheme 4351-06 the target market comprised of built environment practitioners, principally, but not exclusively, architects and architectural technicians new to AutoCAD AEC. The second step involved consulting the supplier's documentation for the command and function set of the particular software product involved. The main purpose of this inquiry was to identify procedures considered most relevant to the trainees targeted. Once a collection of relevant software commands and functions had been assembled attention focused in Step 3 upon identifying 2D drawings and 3D models to provide content for their application. In order to contain development costs and reduce uncertainty the authoring group tended to prefer reuse of existing data than specification and production of new material. Stage four in the process involved preparation of step-by-step paper-based activity sequences to link the relevant software procedures. In a parallel activity questions and multiple choice answers were generated to test knowledge of facts and understanding of concepts associated with use of the CAD software in the targeted commercial environments. One key consideration for both activities was ability of the typical trainee with corresponding instruction to perform adequately in production of the 2D drawings and 3D models, and respond to the question set in an acceptable time scale. A second major influence were the formats used by the City and Guilds Institute for its existing CAD training schemes, and the instructional methods used by trainers to prepare trainees for the associated summative assessment. Testing of the resulting documentation was undertaken in Step 5 almost exclusively by the authors themselves, or other trainers. The central criteria for evaluating such tests were whether the practical tasks were achievable in the specified time, and accuracy of multiple choice question sets. On successful conclusion of Steps 1-5 of the instructional design process the resulting documentation was submitted to the Institute for internal checking, standardising in accordance with its current conventions, and subsequent publication. By comparison with the breadth of analysis required by Romiszowski's (1984) paradigm (Fig. 11, p77) the process and methods used by the authoring group and discussed here are highly constrained.

Alternative training interventions

In practice problems with training in CAD for building surveying typically originated from a combination of all three potential causes identified on pages 134-135 and discussed on pages 135-148, namely inadequate analysis, resourcing and management of CAD, deficient policies and provision for staff development, and methods used for training. An extreme example of how such constraints could interact for a small practice was provided by Midhurst-based Y10 which in 1995 considered that use of CAD was part of a solution to restructuring of the sole proprietor operation enforced by difficult economic conditions. Development of requisite knowledge and skills was severely constrained for the building surveyor involved, however, firstly by use of an aging CAD system with a small user base in the wider market. This difficulty was compounded by limited availability for instruction because of other demands of workload, the unsuitability of those CAD training courses generally available, and the high cost of more individualised provision. The more extreme case of practice Y12 in Henley-On-Thames provided stark evidence that external factors could prove terminally damaging for use of the technology, regardless of conditions of human performance and staff development:

> "Unfortunately due to the substantial loss of our Client base during the recession, resulting in the shedding of staff, we have abandoned the use of CAD."[1]

Staff development for appraisal, management and development of CAD

Based upon evidence discussed on pages 118-120, staff development was required in many cases to enable effective monitoring and review of the role and performance of CAD in practices with the technology, or its potential for development in those without. More specifically the need was apparent for developing capabilities to analyse opportunities, requirements and constraints, and identify an appropriate CAD strategy for the practice, with clearly defined and achievable provision to resolve human performance deficiencies. Experiments with part-time building surveying students at De Montfort University[2] indicated widespread difficulty appreciating the need for analysing information processing requirements in the workplace, or to consider alternative strategies for implementing computer systems. This deficiency was particularly evident amongst two distinct categories of practitioner. The first group comprised of recent CAD enthusiasts with relatively little direct experience of the technology. The second category included those required against their preference to use CAD systems. A tendency for concentrating upon practical application of the software to current workload, regardless of implementation issues, was considerably more widespread. In marked contrast, the need for a coherent implementation strategy was usually more apparent to those with first-hand experience of the difficulties a practice could encounter with the technology. These characteristics indicated the potential difficulties that staff involved with devising and implementing appropriate CAD strategies were likely to encounter. Their progress was likely to be constrained by persistently low appreciation

1 Letter from Keith Douglas FRICS., ACIArb., FBEng., FIAS., 27 February 1995.

2 Undergraduate modules BEBS2005: Information Technology Studio, 1998-9, and CNST2008: Design and Construction Processes Studio 3, 2000-1, with part-time students Bsc.(Hons) Building Surveying students from Year 3 and 4.

elsewhere in the practice of the need for policies and actions identified, and the implications of such strategies for changing existing procedures and modus operandi.

Software system and application independent instructional model for developing practical capabilities with CAD

As a logical progression of the preceding analysis the remainder of the research programme focused upon resolving inadequacies of methods for developing practical capabilities with CAD identified on page 135 as Cause 3 of the problems experienced by practices with training. This was undertaken in the context of deficiencies in the analysis, resourcing and management of CAD (Cause 1), and inadequate policies and provision for staff development (Cause 2).

Prerequisites for an effective alternative instructional model are capabilities for distinguishing the extent to which problems achieving productive use of CAD in any particular practice originate from the management and resourcing deficiencies (Cause 1) discussed on pages 78-117, or from human performance deficiencies responsive to appropriate training policies and methods. Depending upon the timescale and availability of resources the required analysis may be undertaken for individual cases by suitably knowledgeable staff within the practice, or in combination with external consultants. Where the practice is without adequate in-house capability for this purpose then staff development indicated on page 149 will be needed.

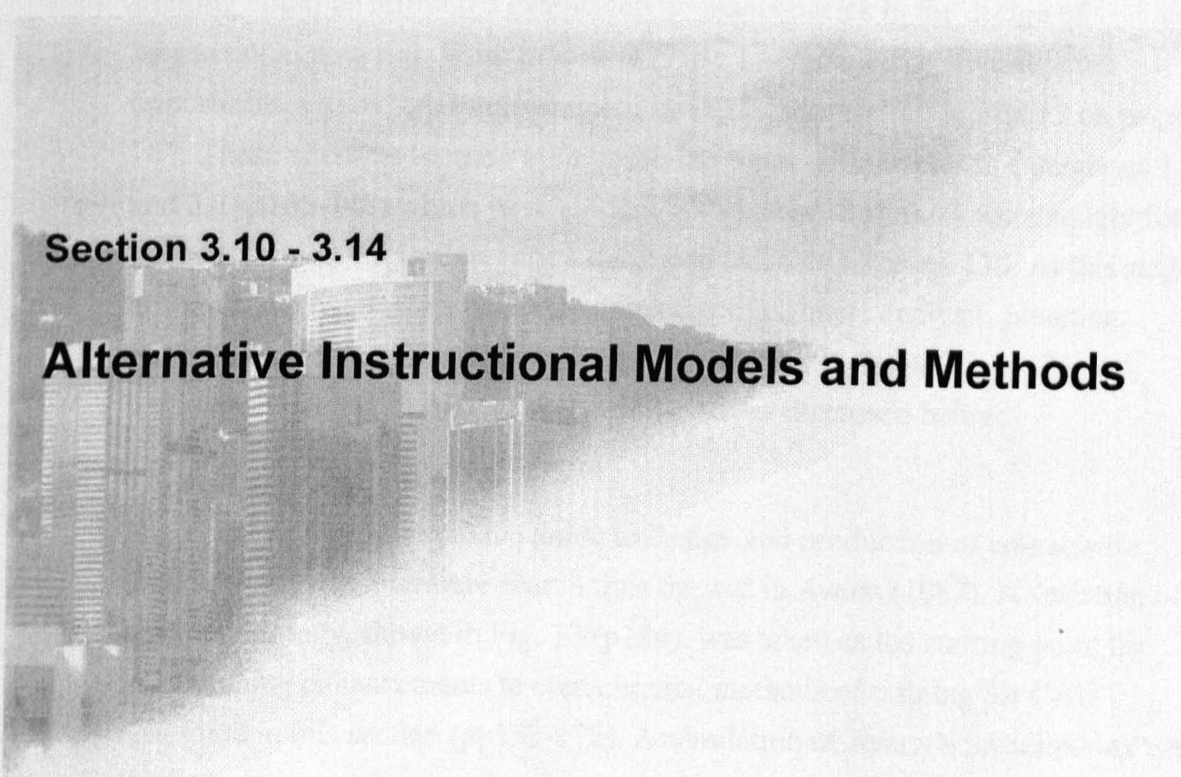
From deficiencies observed in the planning, design and delivery of conventional training discussed in pages 142-148 it was clear that where Romiszowski's analysis (Fig. 11, p77) indicated an authentic requirement to develop practical capabilities for using CAD then the training methods generally available were likely to prove variously inadequate for that purpose. Variations in the responses of practices to CAD, identified from the 1995 survey and discussed on pages 59-75, strongly indicated that training for use of the technology in building surveying should not be confined to general methods and indicative content, but instead deal effectively with locally expedient application of available systems to authentic components of workload and working practices. A need for individualised instruction was further indicated by variations in the extent to which practices had achieved improved productivity, and in their solution rates for problems applying CAD to specific tasks. Medium sized practices had achieved a solution rate of 50% to such problem whilst those small practices in the sample were still trying to resolve their difficulties (Table 9, p72). Further evidence of the need for individualised provision was apparent from variations in the application of specialised add-on software. An explicit instructional model, independent of CAD software system and application characteristics, was required enabling providers of in-house and external training interventions to individualise provision for a particular practice and trainee. A suitable model would need to be responsive to a range of issues. In the first instance it should be capable of responding to variations in the development priorities expressed by a practice. It should also be responsive to the inherent tendency of CAD for requiring additional knowledge and practical capabilities of users as the technology developed in successive releases of the software, or as modifications were made in local application methods to service changing demands for building surveying services. Evidence of the benefits of shared responsibility between technician and professional staff for CAD-related tasks indicated that the model should also be capable of developing more effective methods of collaborative working.

An implication of the conflict identified between the sequencing of processes for cost-effective application of CAD in the workplace, and progression required in learning activities to develop corresponding understanding, knowledge and skills, was that an alternative model should raise a trainee's awareness of commercial methodologies and their rationales. This objective should be achieved, however, through activity patterns conducive to effective instruction and learning.

An alternative instructional model should also require and respond to reinforcement, practice and development of knowledge, understanding and ability outside of formal training events. Similarly it should provide for subsequent development of applications in the workplace. Such methods are particularly needed in practices starting up with CAD, and in those attempting to develop capabilities for additional applications with little or no existing in-house CAD expertise. Ways should be sought in this connection of achieving a self-sustaining momentum for group learning where such is perceived as beneficial by trainees and the practice. The model must also include mechanisms for monitoring and moderating tendencies for staff to engage in developments that are insufficiently relevant to the agreed strategy for application of the technology.

An alternative instructional model should, moreover, be responsive to the need for instruction and learning to use specialised add-on software identified as integral to the practice's CAD capability. Conversely, where a practice's CAD strategy has identified that provision and use of specialised additional resources are nonviable then instruction may be needed for enabling staff to apply those CAD resources that are available for authentic tasks, regardless of the normal classification of software or output achieved (Chart 23, p94). The model may also be required to develop the trainee's ability for finding ways of circumventing inadequacies in available hardware or software resources.

Notwithstanding the limitations discussed on page 141, self-directed learning and on-the-job instruction by in-house personnel were clearly the most achievable training methods for CAD building surveying practices at 1995 (Table 16, p139; Chart 37, p134). An alternative instructional model would need to capitalise upon this propensity. Successful implementation of an alternative model in any particular case would also require management and resourcing action as the primary remedy for constraints on staff availability for reinforcement, practice and application which limited development of practical CAD capabilities, particularly in small organisations. An alternative instructional model should, however, anticipate a residual incidence of such difficulties in any particular practice. Corresponding provision should be made as appropriate for self-directed remedial and refresher purposes.



Section 3.10 - 3.14

Alternative Instructional Models and Methods

3.10 Enhancing conventional methods

The second objective of the research programme was to develop, test and assess alternative instructional methods for acquiring and developing CAD skills, as described for Strand 2 of Task 4 on pages 39-40. Research and development proceeded through the five phases summarised in Table 4, page 40, with the results discussed on, pages 153-381. As indicated on page 57, however, R & D Phases 1, 2 and part of 3 of the research programme, reported in Sections 3.10, 3.11 and part of 3.12, predated availability of the 1995 survey results considered in the preceding Sections 3.2 - 3.9.2 on pages 58-152. For similar reasons work and results reported in Sections 3.10 - 3.11 was undertaken before various significant sources of instructional theory had been located or assimilated later in the research programme. At this stage of the investigation a generally held assumption also prevailed with the author that limitations on the effectiveness of training could be attributed extensively to inadequacies in the design of instructional material. Work in R & D Phase 1 responded by investigating opportunities to enhance conventional methods summarised in Fig. 12 on page 147. These attempts focused upon resolving those deficiencies in Categories 1 and 2, (pp135-148) which were evident at this point. Solutions were sought for Defects 1.1 and 1.3 in Category 1 described in Table 15, page 136. At this stage, however, the emphasis was upon addressing inadequate analysis, planning, design and production processes in defect Category 2 (Table 17, p143), and particularly Defects 2.1-2.5, 2.7-2.8 and 2.10[1] as discussed below.

Theoretical basis

The clearest, most practicable guide to design and production of courseware found through the literature search thus far was in Ayerst (1987). A variation of his methodology, shown in Fig. 13 (p154), was taken as the starting point for investigating enhancements to conventional methods of training for CAD described in this section (pp153-172). Assimilation of Ayerst's prescriptions was the first step in addressing the observed lack of concern with explicit and rigorous instructional design methodologies evident in Defect 2.2 (Table 17, p143).

1 Subsequent numbered references for defects relate to column 2, Table 15, page 136, or Table 17, page 143.

1. Identify:
    1.1. Target population.
    1.2. Learning objectives not met by current training provision.
    1.3. Constraints on, and alternatives to, current training provision.
    1.4. Preferred training strategy.
    1.5. Information and other resources required to achieve objectives.
    1.6. Scale and composition of instructional package.
    1.7. Progress reporting for instructor and trainee.
    1.8. Evaluation strategy for courseware and its performance in use.
2. Cost project.
3. Timetable production.
4. Flowchart instructional package.
5. Produce package.
6. Validate instructional package.
7. Use, review and revise instructional package.

Fig. 13 Enhanced methodology for design and production of training for CAD (after Ayerst 1987)

Target population and learning objectives

Step 1.1 of the adopted method required consideration of the target population for instruction which, in this case, was evidently building surveyors as a relatively small group of end users with distinct requirements for applying CAD. Partly in response to observed demand, but also to restrict the range of issues for consideration, the population was specified more precisely as newcomers to CAD, or those with previous experience of the technology other than with the target software system. Identifying trainees in this way addressed Defect 2.1 whereby conventional training methods tended to distinguish only crudely between introductory, intermediate and advanced categories. Step 1.2 in the process was to identify learning objectives not met by current training provision. Work elsewhere in the programme to identify the requirements of practices for CAD applications and training were being hampered by the lack of published information, as described on page 28. Discussions with practitioners, and the published evidence which was available, for example from Howard, Kirk and Bunyan (1991), suggested that the primary learning objectives should focus upon 2D drafting with AutoCAD as the application and software combination predominating in practice. This corresponded accurately with subsequent findings from the 1995 survey as indicated in Chart 18, page 85, and Chart 31, page 121.

Constraints and alternatives

Step 1.3 of the method involved consideration of constraints upon, and alternatives to, current training provision. Investigations for these purposes were continuing through the literature search, discussions with representative personnel, and classroom observations (R & D activities 1.1, 1.3, 3.1, 3.2, Table 5, p43). Analysis for the interim was consequently based upon constraints apparent in Categories 1 and 2 on pages 135-148, with alternatives limited to modification of conventional methods rather than radical alternatives.

The prevalent culture of the CAD insider which characterised Defect 1.1, was observably unhelpful for most trainees learning the software, or for its productive subsequent application. This constraint might be counteracted by adopting demystification of CAD as a guiding principle for design and delivery of instruction. The process would logically begin with introduction to essential components, concepts and techniques of the CAD system and its interface as an explicit activity.

Defect 1.3 had identified that where training included significant promotion of the subject CAD software system for the commercial benefit of the manufacturer or supplier it usually constrained trainees, instructors and instructional resources from fulfilling their primary functions in the learning process. More potential for effective engagement with the software was anticipated through emphasising objective, critical appraisal of the CAD system, and awareness of the developmental nature of the technology.

The tendency of conventional CAD training to polarise instruction between general methods with indicative content at one extreme, and elaboration of software technicalities with little authentic application for the target population at the other (Defect 2.3) might be substantially remedied by selecting content from the characteristic workload of building surveyors with existing buildings, and emphasising technicalities of the CAD system only as necessary to achieve authentic requirements. 2-D drafting from measured survey data and space planning were therefore selected as authentic building surveying applications of CAD. Worksheets dealt with more specialised software procedures only as authentic content required, for example alternative techniques for defining arcs to intersect diagonal and parallel measurements when plotting measured survey data.

To help counteract the preoccupation of conventional CAD training with new structures (Defect 2.4) practical work could be more productively based upon the premises in which instruction and learning took place. As a result trainees would be able to inspect and measure parts of the building as required when representing its structure, or manipulating its spatial arrangement.

Examination of conventional training methods had shown little provision for variations in the previous experience and learning preferences of trainees (Defect 2.7). This was most apparent where generic, paper-based instructional material had been designed for longevity with a wide user base (Defect 2.5). A range of methods might be used to accommodate variations in previous experience and learning preferences, including suitably detailed step-by-step instructions in hard copy documentation, and on screen, for novices. Clearly marked routes would be needed, however, for more experienced trainees to bypass superfluous guidance. Provision should also be made for instructing novices in use of learning resources integral to the CAD software, for example in techniques for making effective use of proprietary online help facilities. Clear guidance should also be provided for enabling beginners to resume practical work outside of formal training events, and follow appropriate procedures to save their work and exit the software system at the end of a self-directed session.

Instructional methods observed up to this point in the investigation did not appear to achieve an adequately productive relationship between opportunities for assimilating technicalities of the software and following the activity pattern of an accomplished CAD user (Defect 2.8). Scope for designing instructional sequences to provide for both purposes needed investigating.

Attempts were made to offset counterproductive consequences of trainees following step-by-step instruction, for example a lack of independent inquiry and experimentation. One example involved construction of a room outline by overlaying offset lines from polyline to clarify operation of the erase command.

Steps 1.4-1.8

The preferred strategy identified in response to Step 1.4 of the method to incorporate alternatives discussed on pages 155-157, is referred to as Instructional method 1. The scale and composition for the strategy decided through discussion amongst the training team and with the client in response to Step 1.6 are indicated in Table 18.

Presentation			Practical exercise	
Number	Title	Tuition (hrs)	Title	Tuition (hrs)
1	Course Outline and CAD Essentials	1	Elements of a CAD System : An Introduction to AutoCAD	4
2	Drawing with Computers	1	2D Drafting with AutoCAD : Basic Concepts and Techniques	8
3	Designing in 2D with Computers	1	Designing in 2D with AutoCAD - Basic Concepts and Techniques	8
	General	1		
	Total	4	Total	20

Table 18 Content for an introductory training course in CAD based upon Instructional method 1

Preparation of resources specifically for the target population addressed the tendency in conventional training for over-reliance on generic instructional material prepared for longevity with a wider user base, (Defect 2.5). In response to Defect 2.10, reuse of existing instructional material, modified only minimally to accommodate new releases of CAD software the instructional material was designed specifically in response to the deficiencies identified by analysis of conventional methods. Content and instructional methods were selected for their relevance to the authentic workload and prior learning of the trainees involved.

The principal components of instructional method 1 (resulting from R & D methods 3.1, 3.2, 3.5.1-4 in Table 5, p43), shown in Fig. 14 (p159) were formal presentations by instructors, planned and ad hoc demonstrations with the CAD software, and practical work led by the instructor with reference to paper-based worksheets. The ratio of time between formal presentations and tutored events was 1:5.

Information and resources

Step 1.5 in the enhanced methodology (Fig. 13, p154) required identification of information and other resources necessary for achieving the specified learning objectives. Presentations were made accordingly by the instructor conveying information verbally on context, concepts and techniques to groups of up to 12 trainees, supported by visual displays and hard copy documentation. Planned demonstrations were made by synchronous use of the subject CAD software and standard projection capabilities. Ad hoc demonstrations were made as required by either the instructor or trainees using their workstations or, for aspects of wider interest, the available projection capabilities. Paper-based work sheets formed the central resource for instruction and learning in practical exercises.

Mechanisms to help demystify the technology in response to Defect 1.1 included:

- Clear statements of objectives, content and methods (Fig.15, p162)
- Engagement of trainees with general concepts and principles, for example characteristics of the software interface, coordinate systems and measuring conventions, structuring of data through layering, before proceeding to specific application of the CAD system.

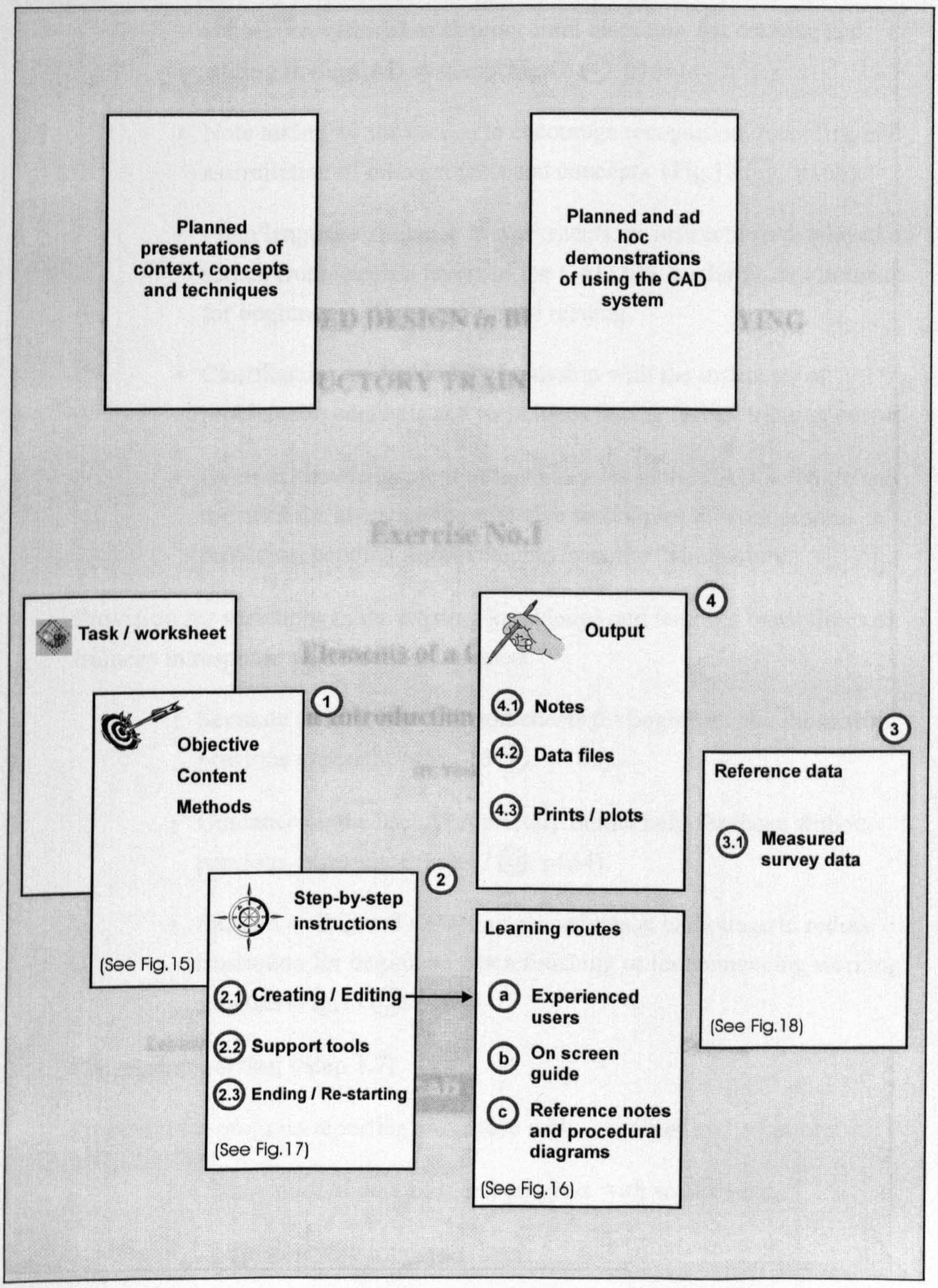


Fig. 14 Instructional method 1: Main components and their interrelationship

- Step-by-step instructions linked to flow charts of command sequences, referred to as procedural diagrams, for creating and editing in the CAD system, (Fig.16 (c), p163).
- Note taking by the trainee to encourage recognition, recording and assimilation of relevant facts and concepts (Fig.18 (4.1), p165).
- Plain language guidance in worksheets, or instructions displayed on screen from specific layers of the CAD file, to clarify requirements for beginners without prolonged reading.
- Clarification on demand in discussion with the instructor of problematic concepts and techniques during formal training events.
- Overt acknowledgement of inadequacies in the CAD software and the need for investigating effective techniques to work around problems, pending improvements from the manufacturer.

Provision for variations in the existing knowledge and learning capabilities of trainees in response to Defect 2.7 included:

- Separate routing through worksheets for beginners and those with previous experience (Fig.16 (a), p163).
- Guidance on the use of proprietary online help for those without previous experience (Fig.17 (2.2), p164).
- Explicit ending and restarting procedures at each stage to reduce frustration for beginners when finishing or recommencing working sessions (Fig.17 (2.3), p164).

Progress reporting (Step 1.7)

Provision for progress reporting was made with user notes and printout for:

- Observation of data files and progress with worksheets.
- Discussion with trainees.
- Log of restart steps.

Evaluation strategy (Step 1.8)

Step 1.8 of the enhanced instructional method required an evaluation strategy for courseware and its performance in use to address the general disinclination and inadequate mechanisms identified in Defect 2.10 for reviewing the effectiveness of training. Observation of activity and discussion in formal training events with inspection of the trainee's output provided the main evidence for assessing the effectiveness of Instructional method 1. Provision was also made to consider verbal and written feedback from trainees and their sponsors.

Steps 2-6

R & D Phases 1-3 utilised requirements of commercial and academic clients for training services of Leiceter CAD Centre to identify and test methods for Steps 2-6 (Fig. 13, p154). Instructional method 1 was costed and timetabled in Steps 2-3 through discussion between the Centre and Leicester City Council, the Building Surveying Department at De Montfort University and the British Shoe Corporation. The City Council as the initial client principally funded the project. The introductory training course (Table 18, p157) was flowcharted in Step 4 of the process using an A1 columnar layout in a 2-D CAD file to represent and interrelate the various presentations and practical tasks from a combination of hand-generated schematics and CAD drawings. Worksheets for practical exercises were produced using AutoCAD and desktop publishing software. AutoCAD was used to generate source files for the worksheets, and proprietary screen capture software for recording key stages of a production sequence as graphics files. Captured screen images from the CAD system were assembled with the various supporting text and diagrams, shown in Figs 15-18 on pages 162-165, using the desktop publishing software. External data files were introduced through links rather than embedded objects to facilitate updating, extension, and maintenance of resulting documentation. The initial courseware was validated by a technical assistant at Leicester CAD Centre with no previous experience of the AutoCAD system.

1

Computer Aided Design *in* Building Surveying — Introductory Training Module
Exercise No.2 — 2D Drafting with AutoCAD — Basic Concepts & Techniques

1. INTRODUCTION

1.1. Intended usage & objectives

The purpose of this worksheet is to provide a practical introduction to the basic concepts & techniques of 2D drafting with a Computer Aided Design, (CAD), system. Step-by-step instructions allow new users a self-paced, hands-on introduction to computer-based 2D drafting in general, and to AutoCAD on a personal computer in particular. Those with previous experience of CAD undertake a series of tasks demonstrating the basic operational characteristics of AutoCAD, a widely used general purpose system, and allowing initial comparisons with other software packages.

1.2. Summary of the Exercise

On entering the CAD system users select the "New drawing" option from the AutoCAD Main Menu. Instructions are then given for setting the size, scale and dimension units for a new drawing. Basic line commands are used to represent key elements in a floor plan. Polylines are manipulated, with appropriate automatic alignment via snap settings, to create a plan for two rooms in the building. The display techniques of panning, zooming and redrawing are utilised as necessary. Other manipulative commands are used to incorporate a window detail in the floor plan. The concept of a block is subsequently introduced to group the components of the window detail for manipulation as a unit. Block insertion is then demonstrated as a time-saving feature of the digital drawing system.

On completion of the exercise users will have an awareness of:

- the procedure for starting a new drawing in the AutoCAD system;
- the basic commands & techniques required to generate a simple floor plan in AutoCAD; (The AutoCAD drawing file generated in this exercise is developed in subsequent sessions with other AutoCAD commands & techniques)

1.3. Users with relevant previous experience

Those with relevant experience and knowledge of computer aided design systems may not need to follow each step-by-step instruction in the worksheet. The following symbol appears in the text beside an outline of essential tasks to allow an experienced user's route through the exercise:

Experienced CAD users should, however, complete tasks in the order show.

1.4. Ending & re-starting procedures

Exercise No.2. is self-paced. Users may stop and re-start the exercise as required. Footnotes in the text refer to appropriate ending and re-starting procedures which are described in Appendix A.

Proceed to page E2-9 to start the exercise.

CADBSE21(1) : PC Version : CW : 02-OCT-91 — Page E2-2 —

Fig. 15 Instructional method 1, Component 1 : Statement of objectives, content and methods

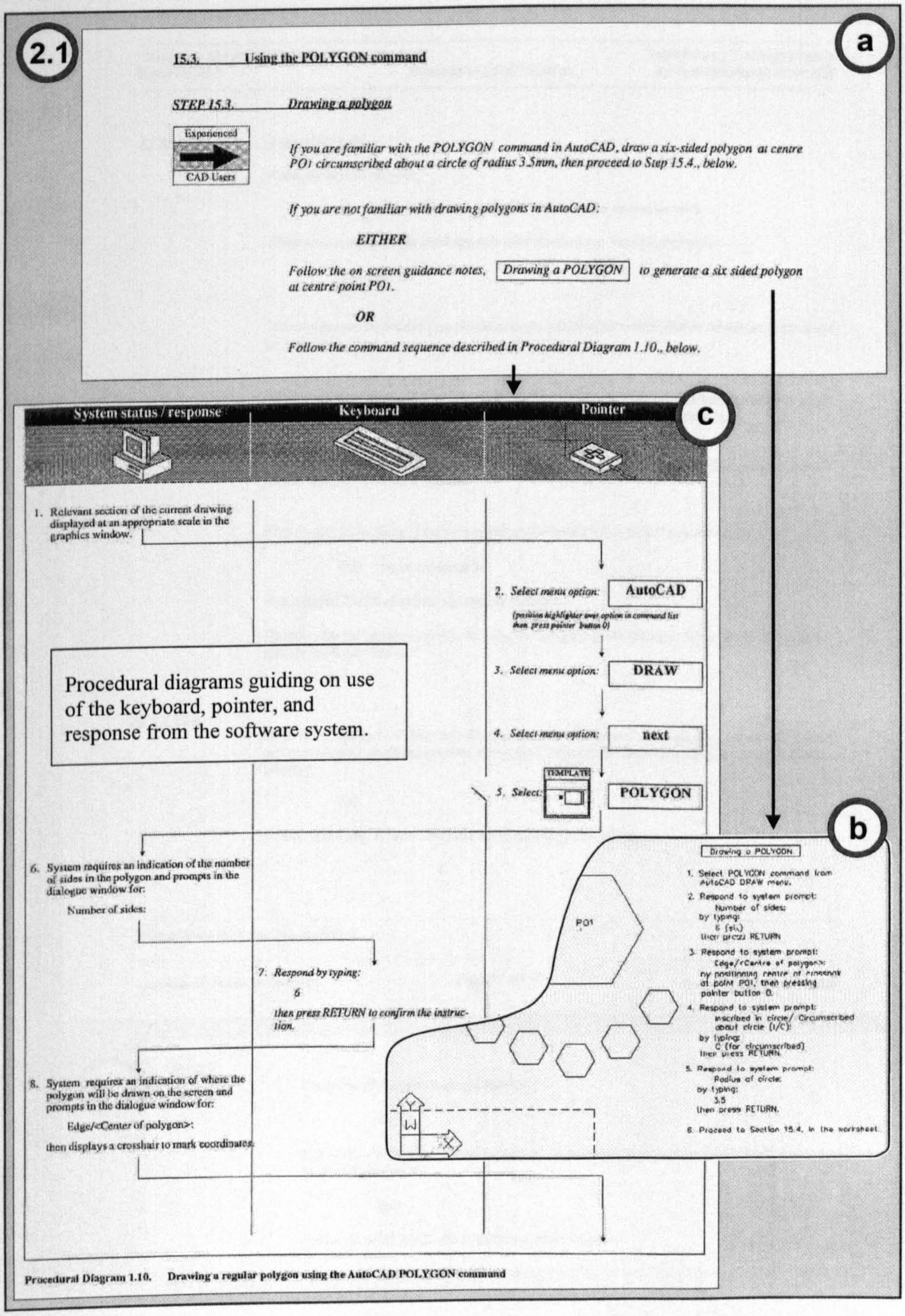


Fig. 16 Instructional method 1, Component 2.1 : Step-by-step instructions: Experienced user route (a); Novice routes on screen (b) and paper (c).

2.2

Computer Aided Design *in* Building Surveying **Introductory Training Module**
Exercise No.1 **Elements of a CAD System** **An Introduction to AutoCAD**

STEP 5.8A ***Requesting help***

From the keyboard, type:

? *(by holding down the SHIFT key then pressing the question mark)*

Observe that the question mark appears after the dialogue window prompt for:

Command:

With the question mark displayed in the dialogue window, press RETURN to submit the help request to the system.

On receiving the request for assistance the system displays a dialogue box labelled Help in which various areas are available to specify and control the display of help information.

Position the pointer arrow in the area at the bottom of the display labelled "Help Item:" and press pointer button 0 to make it current.

With the cursor flashing at the start of the area labelled "Help Item:" type the word:

Line *(upper or lower case)*

then press RETURN to submit the topic to the system.

Observe that the system responds by using the top part of the dialogue box to display descriptive text about the line entity.

STEP 5.8B

Look down through the help text displayed, using the vertical scrolling bars on the side of the dialogue window, as necessary, then click pointer button 0 over the button in the bottom of the display labelled:

OK

to remove the help window and restore the drawing editor display.

To End: Follow End 3 procedure, Appendix A

CADBSE12(1) : PC Version : CW : 29-AUG-92 **Page E1-33** Copyright, LCADC, De Montfort University

2.3

END 3

Complete upto and including Section 5.8.,

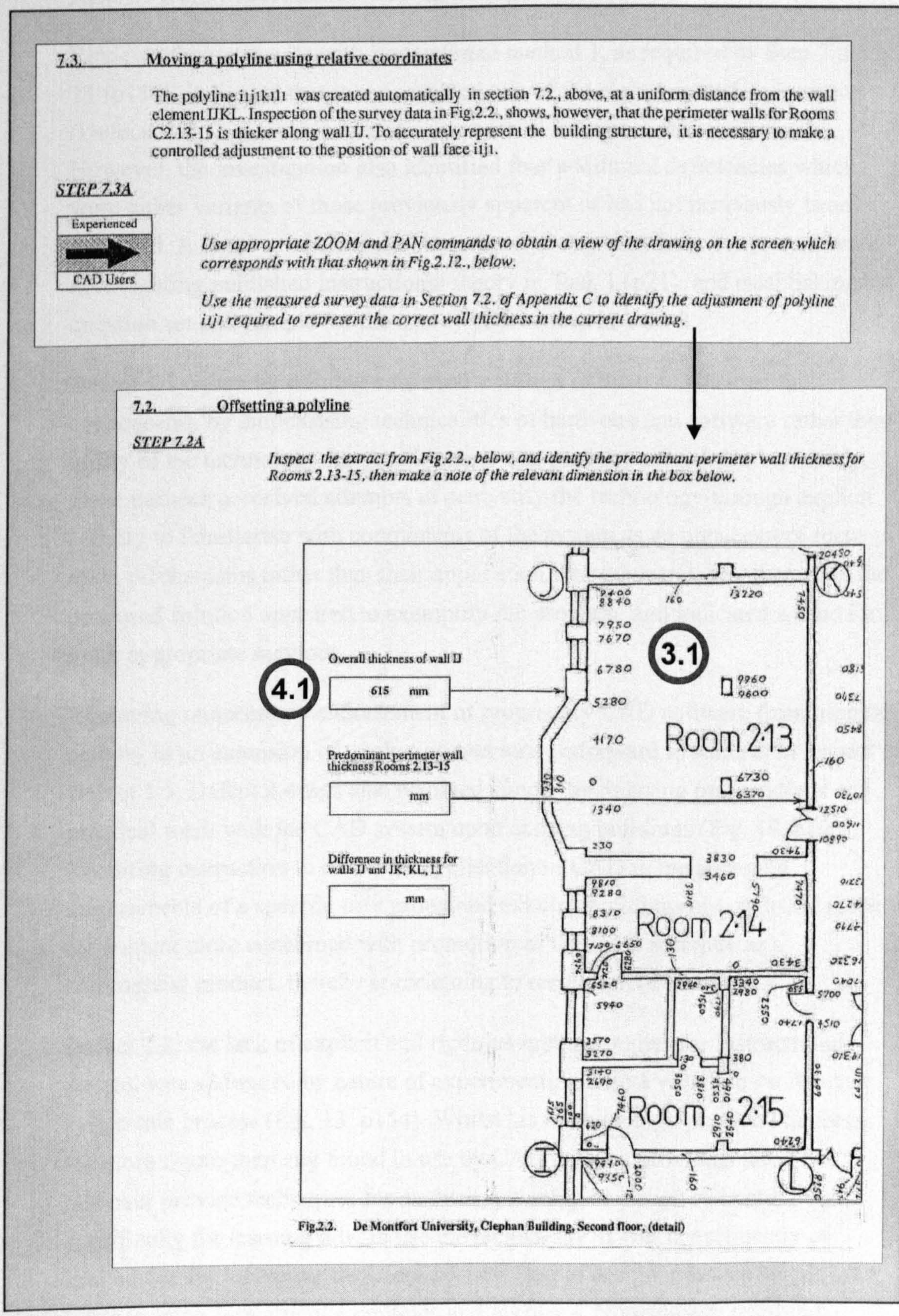
then

Use Section 23 in your copy of Appendix C to note the last section completed and the corresponding re-starting procedure.

then

Follow Steps 22.2A-22.4D to end the working session.

Fig. 17 Instructional method 1, Components 2.2 and 2.3 : Step-by-step instructions for online help , (2.2) Ending and restarting procedures .(2.3)



7.3. **Moving a polyline using relative coordinates**

The polyline i1j1k1l1 was created automatically in section 7.2., above, at a uniform distance from the wall element IJKL. Inspection of the survey data in Fig.2.2., shows, however, that the perimeter walls for Rooms C2.13-15 is thicker along wall IJ. To accurately represent the building structure, it is necessary to make a controlled adjustment to the position of wall face i1j1.

STEP 7.3A

Use appropriate ZOOM and PAN commands to obtain a view of the drawing on the screen which corresponds with that shown in Fig.2.12., below.

Use the measured survey data in Section 7.2. of Appendix C to identify the adjustment of polyline i1j1 required to represent the correct wall thickness in the current drawing.

7.2. **Offsetting a polyline**

STEP 7.2A

Inspect the extract from Fig.2.2., below, and identify the predominant perimeter wall thickness for Rooms 2.13-15, then make a note of the relevant dimension in the box below.

Fig.2.2. De Montfort University, Clephan Building, Second floor, (detail)

Fig. 18 Instructional method 1, Components 3.1 and 4.1 : Measured survey data (3.1), and trainee notes (4.1).

Results from experiments with Instructional method 1

Review of experiments with Instructional method 1, as required by Step 7 in Fig. 13 (p154), indicated that it had resolved two of the eight targeted deficiencies (Defects 1.3, 2.4) and was partially successful in respect of the other six. However, the investigation also identified four additional deficiencies which were either variants of those previously apparent or had not previously been observed. A number of other problems became apparent from concurrent work investigating published instructional theory in Task 1 (p21), and establishing the question set and sample for the survey of practices in Task 2.

Defect 1.1, whereby training enhanced a culture of the CAD insider, or cognoscenti, by emphasising technicalities of hardware and software rather than utility of the technology for practitioners, was partially solved. Unfortunately, some trainees perceived attempts to demystify the technology through explicit activity to familiarise with components of the system as an unnecessary focus upon mechanisms rather than their application. For these trainees, therefore, the proposed solution appeared to exemplify the problem, and indicated a need for more appropriate methods.

Removing unnecessary endorsement of proprietary CAD software from training activity as an extension of marketing was straightforward to achieve in respect of Defect 1.3. Defect 2.4 was also resolved simply by focusing presentations and practical work with the CAD system upon existing buildings (Fig. 18, p165). Requiring instruction to deal with application of CAD to the authentic requirements of a specific user group and existing buildings also reduced scope for content more concerned with promotion of the CAD software as a commercial product, thereby contributing to resolution of Defect 1.3.

Defect 2.2, the lack of explicit and rigorous methodologies for instructional design, was addressed by nature of experimenting with a variation on Ayerst's systematic process (Fig. 13, p154). Whilst his methodology provided the basis for more rigour than any found in use by CAD training providers it did not however provide techniques for analysis, planning or design of instruction specifically for learning how to use the technology. It was consequently of limited use for informing decisions on how best to design, produce and deliver CAD training for particular contexts and purposes. Nonetheless, resulting instructional resources provided trainees, their colleagues and supervisors with tangible evidence of training content and activities from which to assume acquisition of relevant knowledge and practical abilities for application in the workplace. The same material also suggested potential for its beneficial reuse either to refresh those trained initially, or for comparable learning by other staff. Assumptions for effective reuse of training resources by other personnel were flawed, however, for offices where the ratio of CAD seats to drawing staff was high. The 1995 survey subsequently revealed, for example, a ratio of 1:6 in Esher-based practice N05. Limited access to CAD resources would severely constrain independent learning even if training documentation and data files were sufficiently robust for use without concurrent guidance and support from an instructor.

Sustaining the focus of conventional training methods on the design, production and use of generic, predefined, paper-based learning resources tended to perpetuate an unhelpfully simplistic perception of the training process amongst its participants. Adopting this approach encouraged instructional designers, instructors, workplace supervisors, trainees and sponsors to perceive development of CAD capabilities along a predominantly linear route through a clearly identifiable and generally relevant range of difficulty. Experiments with Instructional method 1 revealed this problem as Defect 2.6 and particularly demonstrated that inadequate provision was being made for rapid, independent progress by the trainee. It was also apparent that the core constraints of generic, predefined learning tasks were exacerbated by paper-based instructional methods. In this context Merrill's concern with classification of learning outcomes, and designing appropriate responses (displays), became more significant. Notwithstanding these resilient problems trainees were observed to respond more positively to predefined, step-by-step, paper-based learning tasks where the buildings, sites and CAD application were directly relevant to their current or future workload than where these aspects were generalised or indicative. However, the polarisation of CAD training between general methods with indicative content and elaboration of software technicalities with few authentic applications for the target population (Defect 2.3) could only be regarded as partially resolved by Instructional method 1. Pre-structuring learning tasks and associated resources for general use by the target audience necessarily compromised the relevance of activities, sites and buildings for individual trainees. Although the content of instruction related more specifically to building surveying workload it was not individualised for particular workplaces or their trainees. Such constraints were inherent to the instructional method and would not be resolved by improved analysis of requirements for individual practices. Neither would improving the instructional designer's knowledge of requirements for CAD in building surveying practice resolve an inherent constraint of conventional training methods for production and delivery of individualised instruction and learning, namely over-reliance on generic, paper-based instructional material pre-structured for longevity with a wide user base (Defect 2.5). Experiments with Instructional method 1 indicated instead that CAD training based predominantly on this type of learning task variously frustrated trainees and instructors and contributed less to effective use of CAD in the workplace than participants expected.

Defect 2.8, an inadequate relationship between the sequencing of procedures for cost-effective application of CAD in the workplace, and the order and progression of activities to develop corresponding understanding, knowledge and practical abilities was inadequately addressed in the experiments undertaken. The emphasis upon achieving an effective sequence for introductory instruction left little inherent requirement or scope for the trainee to consider application of the concepts and techniques it contained to an individually authentic drawing.

Instructional method 1 examined various alternative mechanisms designed to rectify Defect 2.7, namely inadequate provision for variations in previous experience and learning capabilities of trainees, or for other constraints on their progress. These focused upon extending the form and structure of paper-based learning resources to accommodate some variations in the existing knowledge, practical abilities and learning preferences of trainees. Experiments included methods intended to enable more independent progress with learning tasks by newcomers to CAD. In practice these initiatives demonstrated limited utility in various cases. Methods tested were observably less beneficial to existing CAD users because of difficulties anticipating their preferred routing through a learning task and corresponding need for explanatory text and images. Whilst some beginners were enabled by the various devices to work through learning tasks with little difficulty they tended not to develop adequate confidence or ability to apply and extend their CAD capabilities with other authentic tasks. Other trainees without previous knowledge and experience of CAD found the content and mechanisms of learning tasks too time consuming and over-prescriptive. In these cases the opportunity to apply knowledge and skills developed in a learning task to authentic workload could appear unnecessarily delayed by involvement with substitute content. Despite apparently clearly specified routes for experienced users through worksheets for learning tasks those trainees with some prior knowledge, understanding and practical ability tended still to receive instruction in concepts, facts and methods which duplicated their existing knowledge or capabilities. In addition to conflicting with their preferences and competence for self-directed learning this problem could mean that those parts of a learning task in which relevant new aspects of CAD were considered could be either overlooked or underused. These results were consistent with Merrill's (1983, p328) observations that:

> "Research on learner control ... shows that merely providing the opportunity for student choice and a rich array of displays [instructional resources] from which to choose are not sufficient. Bright students seem to benefit most whereas less able students need more direction in using the materials available to them."

Overall, therefore, Defect 2.7 was only partially solved by Instructional method 1.

Provision for testing transfer of knowledge, understanding and practical ability to the workplace was frequently inadequate in conventional training for CAD (Defect 2.9). A common omission of even rudimentary testing, and simply issuing certificates of attendance, failed to utilise potential for enhancing the instructional process through timely, well designed, diagnostic, formative and summative assessment. Conventional training tended to use only predefined learning tasks and assume that the ability to identify and implement solutions to CAD problems would develop subsequently and without difficulty in connection with authentic workload. Unfortunately a problematic association was observed in trials of Instructional method 1 with undergraduate building surveyors at De Montfort University between students achieving good marks for completing learning tasks as prescribed but without also developing capabilities for undertaking similar applications involving different data. In an alternative model robust and reliable methods would be required for testing the trainee's performance in response to instruction, and subsequent transfer of knowledge, understanding and ability to authentic applications in the workplace. Moreover, diagnostic, formative and summative assessment during training would be followed by remedial advice and action in the workplace to remedy any remaining deficiencies (Defects 3, 3.1, 2.9, 3).

Variations between practices, their workloads and CAD-related characteristics identified through discussion with practitioners in preparation for the 1995 survey suggested a need for training needs analysis on a practice by practice basis. Training requirements, of for example the Building Surveying Section at the British Shoe Corporation in 1993, indicated despite the trend towards standardisation on PC-based AutoCAD software that individualised content and instruction would remain a requirement for effective learning. Although an improved process for developing resources for instruction and learning was provided through modification of Ayerst's method, the time and effort required to prepare instructional material for individual workplaces were likely to generate significant costs. Indeed, customising courseware for Instructional method 1 to provide for individual practices proved expensive because of the detailed amendments required to the documentation. Regardless of other positive results from R & D Phase 1, experiments with Instructional method 1 indicated that the staff costs and lead times for individualised design and production of the paper-based instructional material involved would be extensively nonviable.

A general disinclination, inadequate mechanisms, and constraints of staff time for reviewing the effectiveness of training in Defect 2.10 left conventional instructional material largely unchanged until client requirements rendered it unusable. Where analysis was undertaken of qualitative data, however, it demonstrated that objective review would clarify defects and highlight the need for change. By nature of its purpose to inform research and development of more effective training methods, and a corresponding review of its effectiveness, Instructional method 1 necessarily addressed a core deficiency. Nonetheless responding in an acceptable period to the CAD particular training requirements of the British Shoe Corporation clearly demonstrated why commercial providers tended not to change their instructional material more frequently. In the event a pragmatic compromise was agreed with the client that customising existing step-by-step material with content from the Department's workload would result in unacceptable additional costs and delay for the necessary analysis, design and production activity.

Inadequate instructional model

For the various reasons discussed above Instructional method 1 failed overall to resolve the deficiencies identified with conventional training for CAD. Due consideration of these results concluded that the model implicit in Instructional method 1 was also fundamentally flawed. Indeed, the model and method were subsequently revealed as an inadequate response not only to the specific deficiencies discussed on pages 131-152 but also to generic difficulties with training identified through the literature search. For a range of original, variant and newly identified deficiencies neither target group of trainees, namely beginners and those experienced with a CAD system other than AutoCAD, adequately developed the capabilities intended. In particular the ability to apply facts, concepts and methods considered in learning tasks to subsequent use of their CAD system(s) with comparable data was not achieved to the extent required and anticipated (Defects 2.5, 2.6, 2.7).

The widespread emphasis by both CAD training providers and their clients upon taught classes as the primary means for developing understanding, knowledge and ability was evidently overstated. An alternative model would require much closer integration of instructional events and taught classes with reinforcement, practice and application in the workplace. Achieving such integration would in turn require instruction more effectively individualised in relation to the authentic workload of the trainee in the practice.

Because of the chronology of R & D Phase 1 in relation to other aspects of the research programme experiments described for Instructional method 1 were also constrained by inadequate theory for the role of instruction in resolving problems of the organisation (Defect 1.2). In particular this accounted for a lack of insight into the constraints on effective use of CAD in building surveying practices. Whilst constrained provision and methods for training needs analysis, planning, design and production (Defect 2) resulted in inaccurate assessment of training needs, Instructional method 1 offered inadequate methods for responding to authentic training needs once they had been identified. Clarification of application and training requirements in a representative sample of the targeted end users was becoming increasingly necessary to inform design of learning tasks for building surveyors. This continuing lack of relevant empirical data to clarify use of CAD in building surveying emphasised the significance of the 1995 survey of practices.

Need for individualised task-based instruction and learning

R & D Phase 1 had sought to optimise conventional methods for training in CAD. Results from Instructional method 1 by the end of this initial phase of research and development indicated that subsequent work would be more productively focused upon developing alternative instructional models and methods rather than continuing to search for well-developed solutions in existing practices and published sources. An implicit need was evident for more relevant and applicable prescriptions of instruction and learning to bridge the gap between theory and practice. Progress in achieving a suitable alternative instructional model would be dependent upon identifying and distinguishing firstly between the relative effects of inadequate analysis which led to inaccurate assessment of training need, and secondly of responding to identified authentic training need with inadequate instructional methods, typically using generic content and catch-all, linear methods (Defects 1, 1.2, 2). On the basis of results from the research programme at this point a clear case was emerging for an alternative instructional model that focused upon individualised, task-based instruction and learning to develop practical ability with CAD.

3.11. Individualising task-based learning

Fig. 19 (p174) shows an initial alternative instructional model (Version 1a) for in-service training in CAD, synthesised using the method described on page 45 in response to:

- Analysis of observed inadequacies in conventional methods of training for CAD (pp141-148).
- Results from practical experiments with Instructional method 1 (pp166-172).
- Discussion with representative personnel from relevant organisations (pp25-28).
- A systems approach to problem solving (See, e.g., Schoderbek et al, 1985).

No comprehensive analysis of instructional models had been identified in the literature search by the start of R & D Phase 2 to inform the initial proposal which drew substantially instead upon systems-based theories and methods for problem solving. Various instructional and learning theories were progressively identified, however, from a diversity of sources in concurrent research activities 1.1, 1.3, 3.2, 3.3 (Table 5, p43) that either corroborated proposals, suggested means of improvement, or could help with implementation, as discussed below.

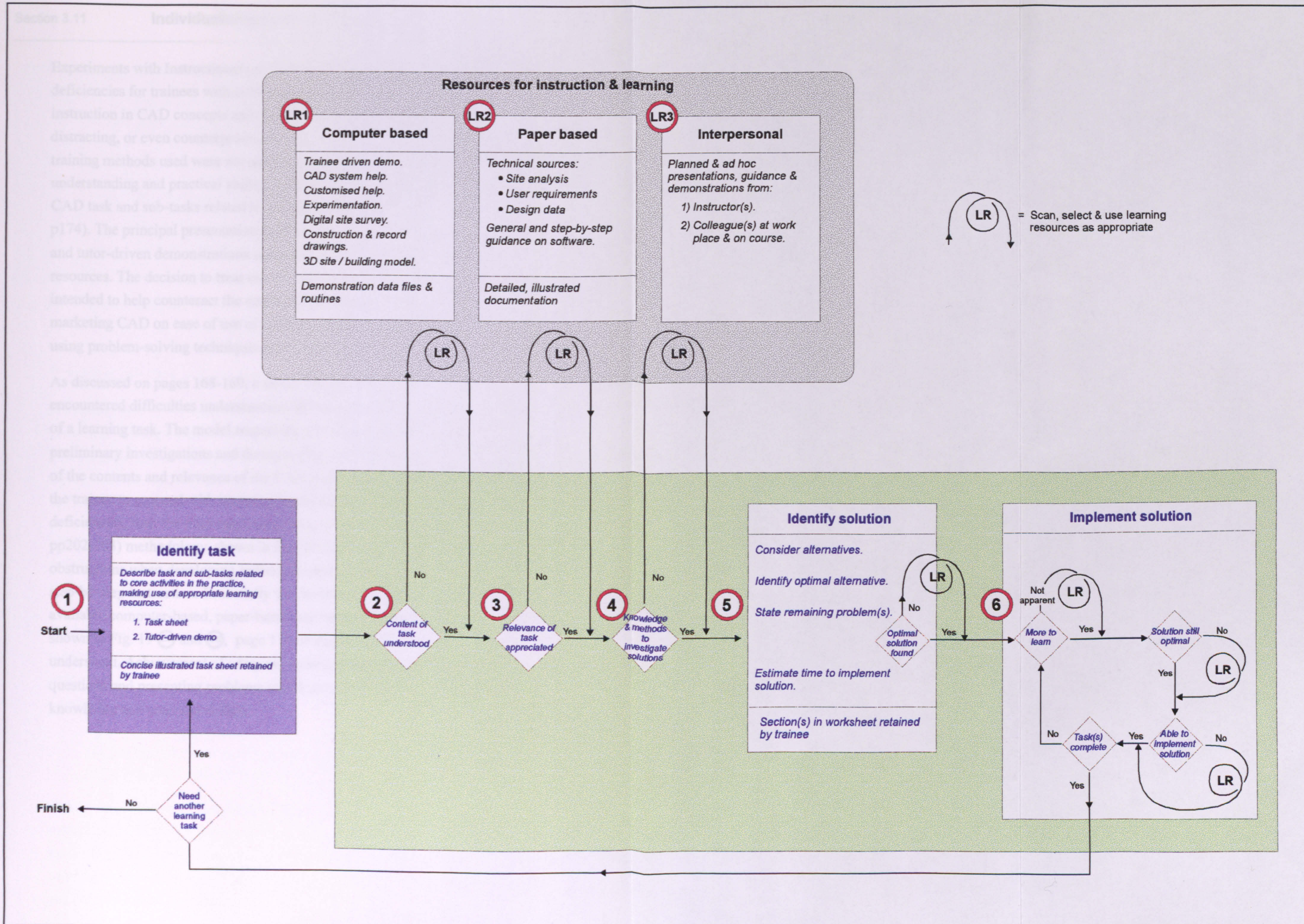
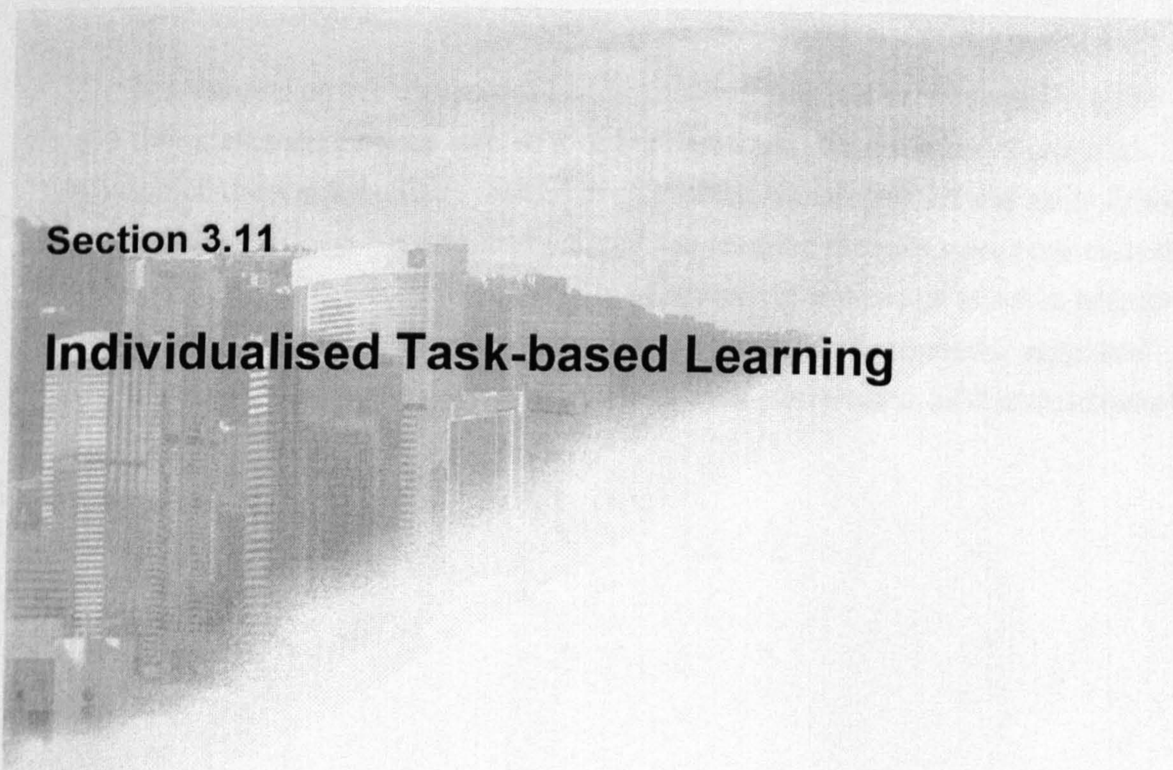


Fig. 19 Initial alternative instructional model (Version 1a)



Section 3.11

Individualised Task-based Learning

Experiments with Instructional method 1 had identified two substantial deficiencies for trainees with previous experience of using CAD. Firstly the instruction in CAD concepts and techniques included for newcomers were often distracting, or even counterproductive, for more experienced users. Secondly, training methods used were not achieving sufficiently transferable knowledge, understanding and practical ability. In the model the trainee is presented with a CAD task and sub-tasks related to core activities in the workplace (Fig. 19①, p174). The principal presentation mechanisms are a concise, illustrated task sheet and tutor-driven demonstrations using appropriate on-line and paper-based resources. The decision to treat use of CAD as a problem solving activity was intended to help counteract the emphasis questionably placed by suppliers when marketing CAD on ease of use of software systems. It also provided scope for using problem-solving techniques from other domains.

As discussed on pages 168-169, trainees subject to Instructional method 1 encountered difficulties understanding the rationale and procedural requirements of a learning task. The model responded with diagnostic assessment during preliminary investigations and dialogue (Fig. 19 ②-④, p174) for comprehension of the contents and relevance of the CAD task, and knowledge and methods for the trainee to proceed with investigating solutions. Where such checks revealed deficiencies, then the tutor responded using a variation on Landa's (1983, pp202-203) methodology, shown in Fig. 20 (p176), for overcoming comparable obstructions when developing individual operations in a procedure through step-by-step instruction. Essentially this involved iteration of selecting from available computer-based, paper-based and interpersonal learning resources, as shown in Fig. 19 (LR1) and (LR2), page 174, to explain what the trainee does not understand. Achievement of adequate understanding was tested by asking questions and presenting problems which provide practice in applying relevant knowledge and practical ability.

1. Select from available learning resources (Fig. 19 LR1 and LR2, p175) to explain what the trainee does not understand.
2. Test the trainee's understanding by asking questions and presenting problems which provide practice in applying relevant knowledge and practical ability.

Fig. 20 Establishing the content and requirements of a learning task with the trainee

Provision, selection and use of instructional resources

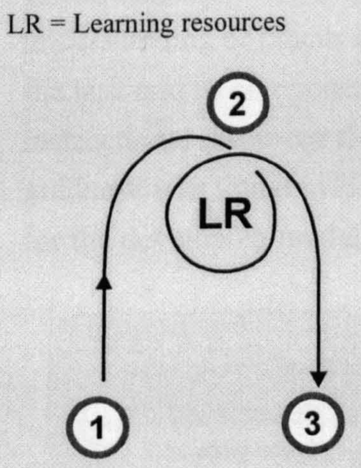
Landa's (1983, p194) recommendation to achieve command of overall procedures through step-by-step instruction was reflected in the overall problem solving sequence of the learning tasks and the proposed structure and modus operandi of the various learning resources, for example Method Summaries, Reference Notes and Procedural Diagrams.

Open access from learning tasks to freestanding learning resources by the process summarised in Fig. 21, page 177, was intended to enable more individualised instructional methods, responsive to changes in the preferences and capabilities of a trainee for learning during a task. Explicit inclusion of experimentation in the range of learning resources was consistent with Landa's advice (1983, pp194-5) to seek an optimal relationship between providing ready-made algo-heuristic procedures and enabling trainees to find their own. Landa (1983, pp194-5) observes, however that:

> "It is perhaps impossible to indicate the optimal proportion of time for teaching students to discover algo-heuristic procedures versus providing them with ready-made ones."

At this stage, however, specific mechanisms to facilitate effective experimentation by the trainee were not apparent. Unfortunately Landa's example (1983, pp204-7) concerned discovery of a general algorithm for identifying phenomena and was not obviously or directly applicable to experimental use of a software system in learning to apply CAD. Nonetheless, the underlying principle was highly germane to inadequacies of Instructional method 1:

> "Teaching students to discover algo-heuristic procedures and getting them to discover any particular procedures is educationally far more valuable than providing them with ready-made procedures and just teaching them how to use them..." (Landa 1983, pp194-195).



Trainee and / or instructor:

1. Identify need for information, guidance or instruction.
2. Scan, select from, and use available learning resources.
3. Trainee continues from appropriate point in learning task.

Fig. 21 General procedure for using learning resources

Revised structuring and use of learning resources is consistent with Scandura's (1983, p224) recommendation to allow for growth of knowledge as learners interact dynamically with a changing teaching environment.

> "The (Structural Learning) theory is neutral on whether this information (to identify the missing portions of the desired...rule) ...should be presented, say, in an expository or discovery manner. Thus, for example, deciding on the appropriate method of presentation depends on secondary objectives that the teacher may (or may not) have in mind (e.g., to help students learn how to detect irregularities)" (Scandura 1983, p222).

What Scandura referred to as "secondary objectives" became apparent through successive Phases of R & D as the need to develop the trainee's capabilities for active learning.

Support for revised treatment and use of learning resources, and guidance for subsequent development was also found in Merrill's component display theory (1983, p282) which recommended facilitating learning by a high level of individualisation and allowing learners to pick and choose strategy components best suited to their momentary state and more permanent traits and aptitudes.

In the initial model the trainee selects as necessary from a suitably varied range of learning resources (Fig. 22) to resolve deficiencies in his or her knowledge, understanding or practical ability which constrain consideration of solutions to the task and its components. Whilst Merrill (1983) advises that specific types of instructional resources should be used for particular instructional purposes, little guidance was found in his published work to indicate the most appropriate type for the developing model, or the trainee's role in their selection and use.

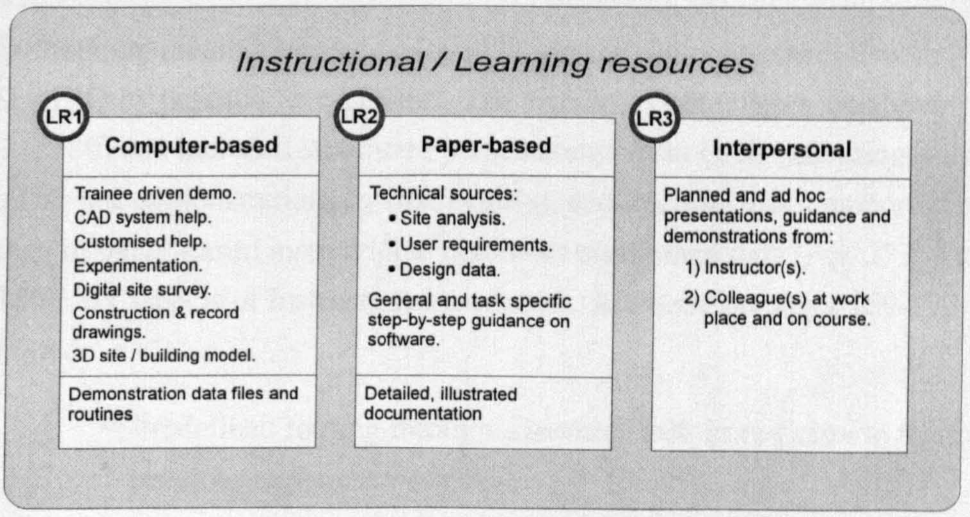


Fig. 22 Revised learning resources for model version 1a[1]

In practical terms freestanding learning resources, as distinct from the Procedural Diagrams and Method Summaries embedded in worksheets for Instructional method 1, could also be used, maintained and extended independently of learning tasks, thereby allowing more efficient design and production of training material in both cases. An indication of initial paper-based instructional material for this purpose is shown in the author's article for RICS Explorer, November, 1991, and

1 Watts, C., et al. (1995). Fig.6, Appendix 5; CADIBS Learning Task No.1. Tested with CADFA trainees, full and part-time building surveying students, Years 1, 2 and 4.

included in Appendix 5. However, the mechanisms by which appropriate learning resources would be identified and accessed for use by trainees when formulating, implementing and reviewing solutions, required further investigation.

The alternative model next requires the trainee to identify an optimal solution, specify any remaining difficulties anticipated with his or her selected method, and estimate the time required to implement the solution. Checks for relevance of the learning activity, and scope to improve the current solution, continue during its execution with the CAD system (Fig. 19⑥, p174). Selective use of learning resources is also sustained to remedy deficiencies which emerge in knowledge, understanding and practical ability as work progresses.

Instructional method 2

Instructional method 2 was developed to test the initial alternative model (Fig. 19, p174) by practical experiments. The principal components are shown in Fig. 23 (p180) and included structured presentations from CAD practitioners, planned and ad hoc demonstrations by instructor(s), and learning tasks supported by a range of paper-based instructional resources and source data (Fig. 23 (3.1) to (3.5), p180). Six aspects of Instructional method 1, discussed on pages 159-175, were omitted:

- Predefined routing through a learning task in response to the trainee's previous experience of CAD.
- On-screen guidance notes.
- Guide to proprietary online help.
- Embedded Reference Notes and Procedural Diagrams in worksheets.
- Predefined requirement for note-making by the trainee.
- Specific, context sensitive ending and restarting procedures.

In Stage 1 trainees were briefed using presentations and demonstrations by the instructor, (Fig. 24 ②, p181), to test and develop CAD techniques for authentic purposes. The brief was designed to enable trainees to experiment freely with CAD functions whilst working within specific technical constraints for the required output files (Fig. 25, p182).

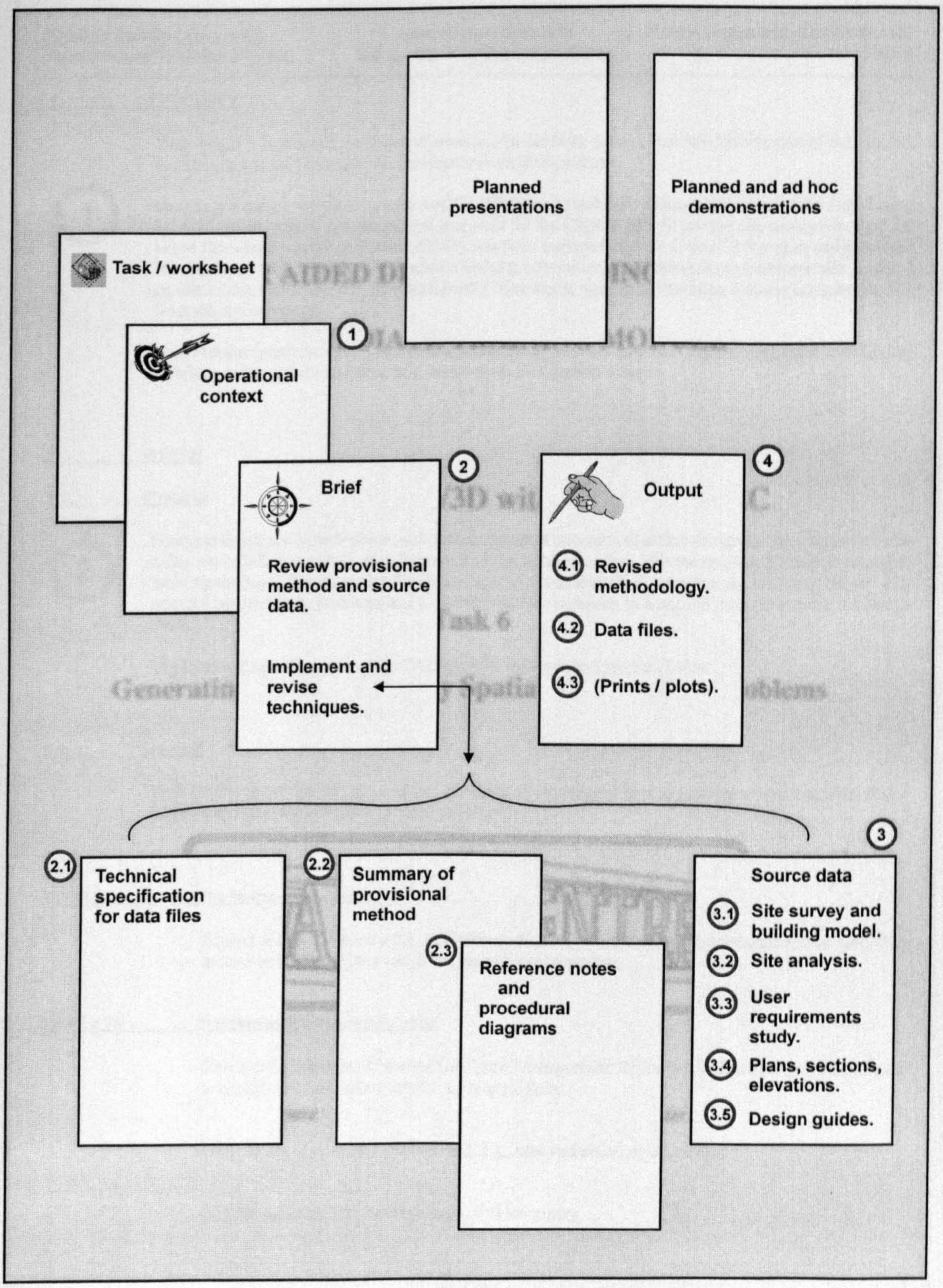


Fig. 23 Instructional method 2 : Overview of components

1. CONTEXT

(1)

Your practice is preparing a sketch scheme and preliminary costings for refurbishing part of the Clephan Building in central Leicester as a conference & exhibition centre.

Based upon earlier experiments with AutoCAD Release 11 and AEC Release 3 the project team intend using 3D CAD techniques to prepare outline proposals for the Clephan job. At present site survey data supplied in the Drawing Interchange Format, (DXF), has been imported into your AutoCAD system and processed in accordance with BS1192, Part 5, related layering conventions.[1] Existing floor plans have been digitized [2] and incorporated within a 3D digital model of essential ground and building features using height data from the site survey.[3]

In this context you have been briefed to test and develop three dimensional CAD techniques for investigating solutions to key spatial and structural problems in the Clephan scheme.

2. BRIEF

2.1. Content

(2)

Examine Guidance Note 6 which outlines a provisional approach to sketch design for the Clephan scheme using AutoCAD Release 11 with Release 3 of the AEC extension. Use the existing 3D digital ground & building model of the site to test the sequence of methods described. Annotate the method summary with relevant observations, problems and improvements for inclusion in a revised practice note for the design team.

The technical specification for the CAD data file is shown in Spec.6.1., below.

2.2. Method

Your brief is to familiarise with, and test, 3D CAD methods rather than to generate a fully functional sketch scheme, and you are advised to proceed as follows:

STEP 2.2A *Preliminary assessment*

Inspect Method Summary 6.1. in Guidance Note 6. in conjunction with relevant source data, then make a note of problems which are immediately apparent.

STEP 2.2B *Implement & review techniques*

Use AutoCAD Release 11 and AEC Release 3 to implement sufficient of the recommended techniques to rapidly test their suitability for current purposes.

Make a note of problems encountered, e.g., time and skills requirements.

Identify and test alternative techniques, as necessary.

Fig. 24 Instructional method 2, Components 1 and 2 : Operational context (1), and Brief (2).

CAD *in* Building Surveying
Intermediate Training Module

Generating solutions to
key spatial & structural problems

Sketch Design with AutoCAD AEC
Task 6

2.1

SOURCE: Site model created in Tasks 4/5 or D:\CADIBS\CBS2ID6.DWG
Existing hardcopy plans, section & elevations at various scales ✓

FILE NAME: conforming with the file naming convention in Fig.6.2., below. ✓

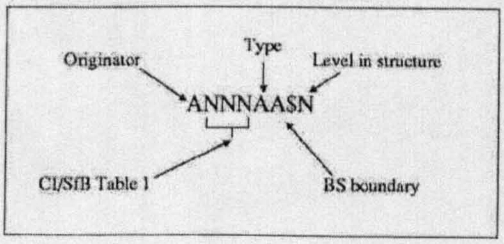
UNIT VALUE: 1 unit = 1 millimetre

HORIZONTAL SHEET SIZE: A2

HARDCOPY SCALE: 1:200 ✓

TITLE BLOCK: D:\CADIBS\T_BLOCK1.DWG ✓

LAYERING: utilising BS1192, Part 5, related conventions in AutoCAD AEC3 ✓



LEVELS & WALL HEIGHTS: ✓

Structure	Level name (and layer suffix)	Level height (mm above sea level)	Wall height
Basement	Level 1 ($1)	60640mm	3370mm
Ground floor	Level 2 ($2)	64010mm	3950mm
First floor	Level 3 ($3)	67960mm	3990mm
Second floor	Level 4 ($4)	71950mm	2900mm

Spec.6.1. Specification for the AutoCAD AEC sketch design files

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Fig. 25 Instructional method 2, Component 2.1 : Technical specification for the output file

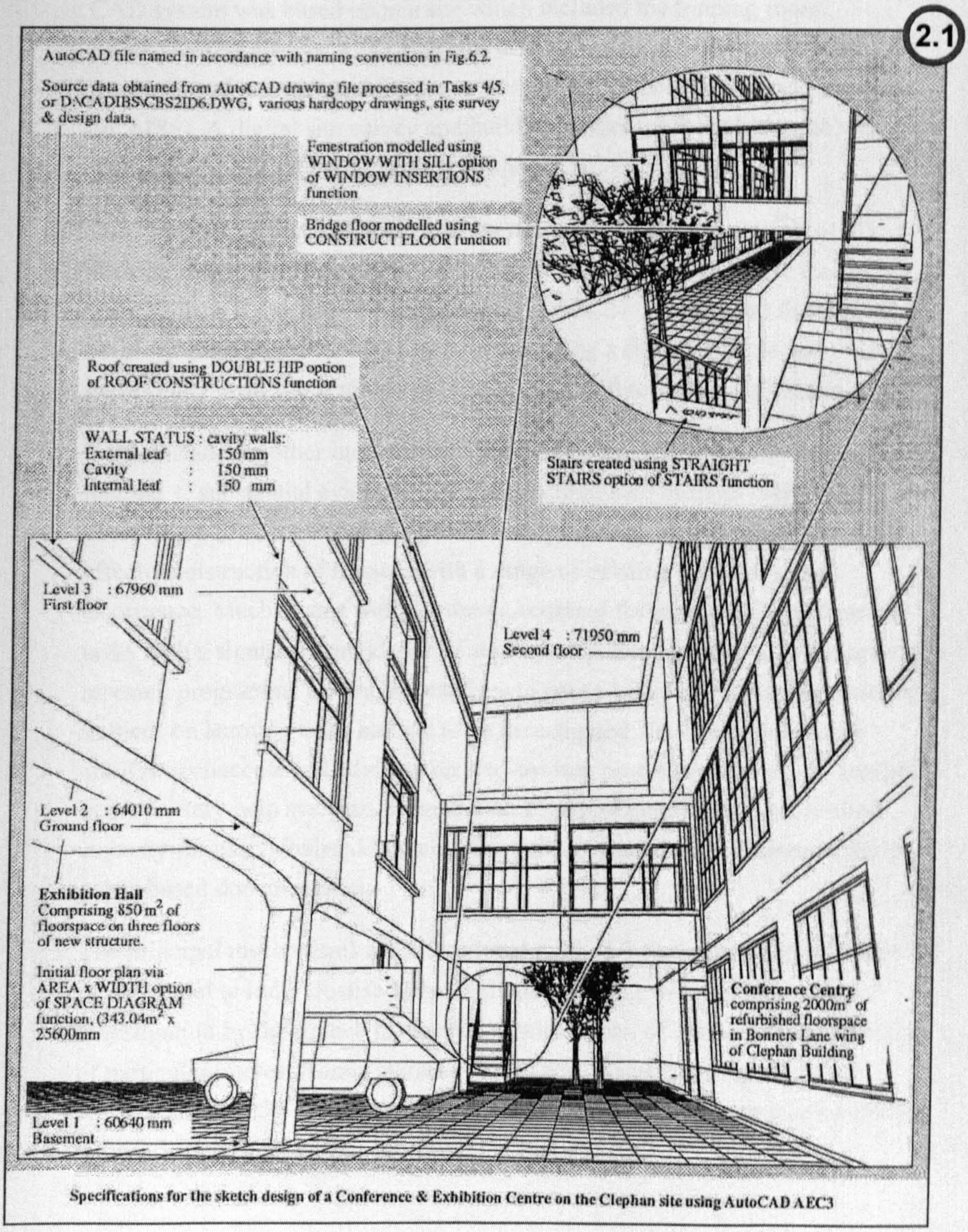

Fig. 25 (cont'd) Instructional method 2, Component 2.1 : Technical specification for the output file

Drawing on positive results from Instructional method 1, practical work with the CAD system was based upon a site which included the training room. Paper-based drawings, a site analysis, user requirements study and design data were collated and indexed for easy access to supplement site inspections (Fig. 26, p185). A digital site survey and building model for the subject site were made available on the local area network.

Task sheets included a statement of operational context (Fig. 24 ①, p181) allowing the trainee to proceed as if work was being undertaken in their workplace. For the case illustrated in Figs. 24 to 27 (pp181-186) the scenario involved investigation of 3D CAD for preparing a sketch scheme and preliminary costings to refurbish the site as a conference and exhibition centre.

Notwithstanding other limitations of the worksheets used with Instructional method 1, substantial evidence had been accumulated through classroom observation of those experiments of the scope in step-by-step directions for effective instruction of trainees with a range of existing knowledge and experience. Mechanisms were, however, required for individualising learning tasks with a significant incidence of step-by-step components. At this stage in the research programme on-line alternatives to paper-based documents for briefing trainees on learning tasks had yet to be investigated. On-line resources for clarifying concepts and advising on step-by-step procedures were only available in proprietary help systems. Despite their high production costs and limited capacity for individualised learning, this role continued to be addressed using paper-based documentation.

The principal mechanisms of Instructional method 2 for implementing Stages 2-4 of the model to individualise instruction and learning were selection and investigation by the trainee in discussion with tutors, of concepts and techniques of particular interest from a learning task. These discussions focused upon consideration of the content and relevance of the task, and the trainee's current knowledge and capabilities for achieving it.

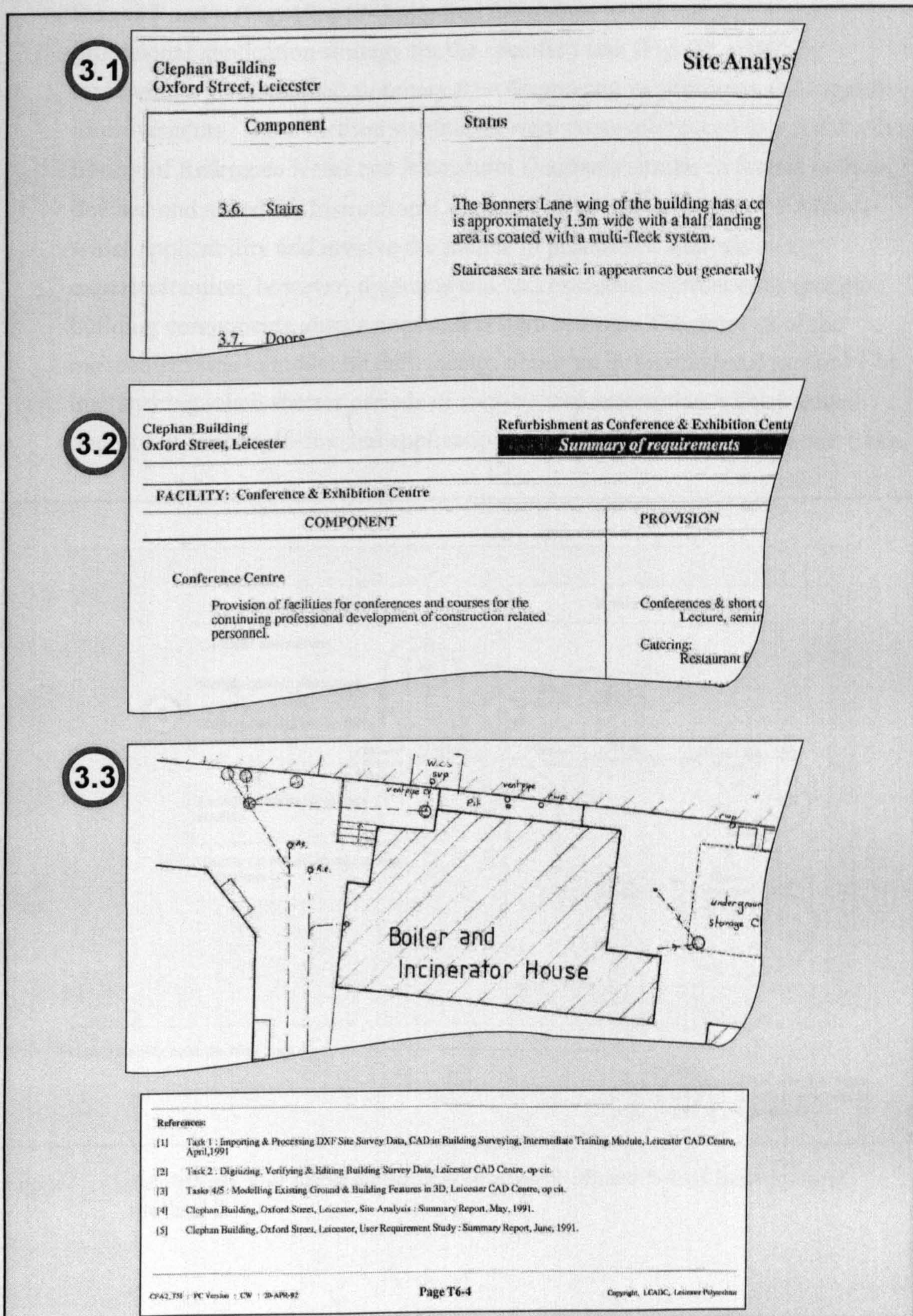

Fig. 26 Instructional method 2, Components 3.1-3.3 : Source data: Site analysis (3.1), User requirements study (3.2), Plans, sections, elevations (3.3) and references to other learning tasks.

Stages 5 and 6 (Fig. 19, p174) required the trainee to test and develop a provisional application strategy for the specified task (Fig. 28, p187) by reviewing a given method summary then diagnosing its problems and suggesting improvements. These method summaries were cross-referenced to a freestanding library of Reference Notes and Procedural Diagrams similar in format to those devised and tested for Instructional method 1 (Fig. 16ⓒ, p163). To achieve wider applicability and involve the trainee in productive analysis and experimentation, however, diagrams and text excluded references to specific building components, dimensions and system settings. The purpose of this mechanism was to moderate deficiencies observed in Instructional method 1 by interspacing much shorter periods of step-by-step instruction with extended opportunities for self-directed application of the CAD system to authentic tasks.

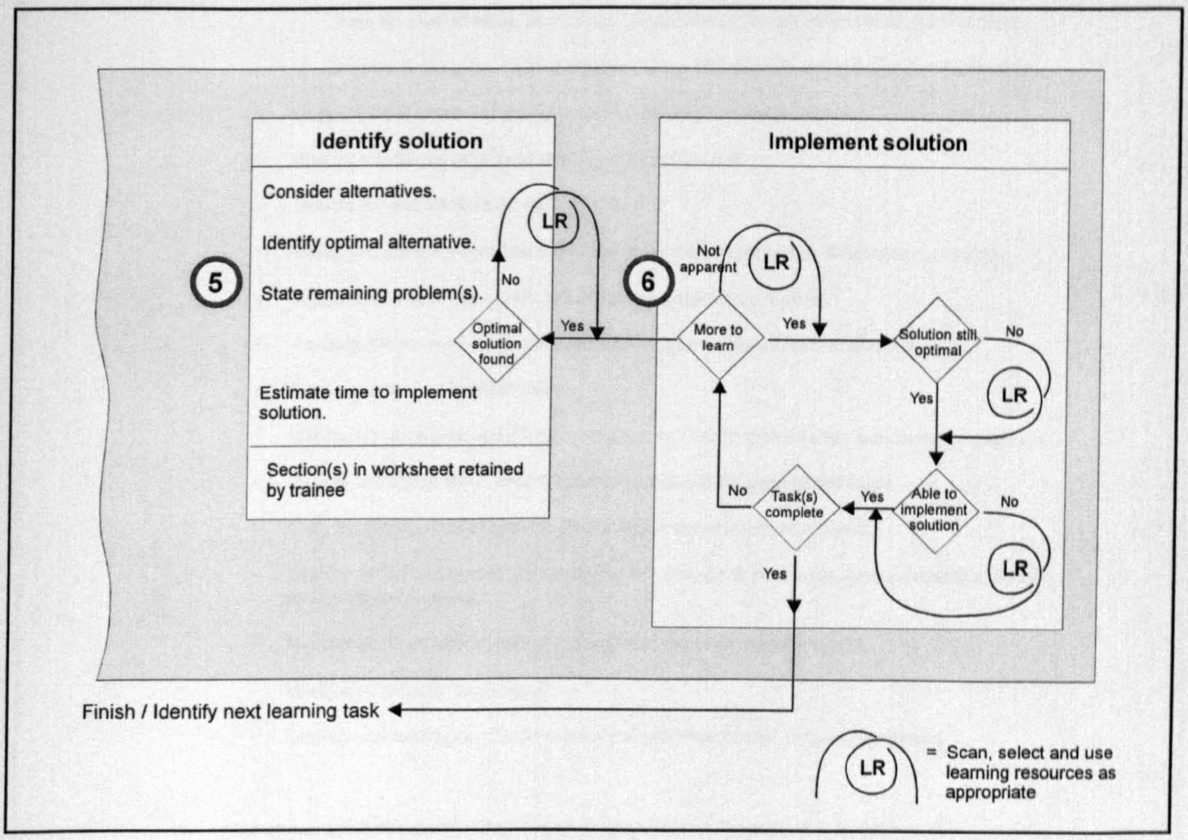

Fig. 27 Identifying and implementing solutions in Stages 5-6 of Instructional method 2

2.2

CAD *in* Building Surveying Intermediate Training Module	Generating solutions to key spatial & structural problems	Sketch Design with AutoCAD AEC Guidance Note 6

1. Analysis of requirements

The design process may proceed in various ways depending upon problems to be resolved and resources available to identify optimum solution(s). AutoCAD Release 11 with AEC may be used to apply a wide range of design strategies to large and small environmental schemes. The preferred approach in applying the CAD system will vary between projects and design teams. Essential features of a common approach to sketch design, based upon an existing AutoCAD digital model of the subject site, are as follows:

- Analyse design requirements and survey data.
- Prepare the source AutoCAD site model for manipulation in AutoCAD AEC:

  Create a new AEC drawing and specify appropriate hardcopy scale & sheet size;

  Insert the AutoCAD source file as a block into the AEC drawing;

  Rotate the block to align the primary axis of the building with the world coordinate system;

  Scale the inserted block, as required, to compensate for any difference in drawing units;

  Explode & purge the inserted block to reduce AEC file size and optimise data processing;
- Copy modified source site model to provide basis for current proposals.
- Specify suitable viewports and save key views of the site.
- Declare suitable levels in the building model.
- Identify structure for demolition and change layer attributes of relevant entities accordingly.
- Suppress display of extraneous data and set required level as current.
- Annotate the site model with key opportunities, constraints and user requirements.
- Set parameters for structural walls.
- Use inquiry commands and 2D space diagrams to identify spaces for key activities diagramatically.
- Process two dimensional space diagrams to produce three dimensional forms.
- Copy basic enclosures of space to other levels in the structure, as required.
- Resolve spatial and structural implications of vehicular & pedestrian access, circulation, parking and egress requirements.
- Incorporate floors, stairs, roofs, doors and windows in the building model.
- Model hard and soft landscaping.
- Evaluate and modify the sketch proposal and generate alternative(s), as appropriate.

Appropriate techniques are described in more detail in Method Summary 6.1., below.

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Fig. 28 Instructional method 2, Component 2.2 : Provisional production method

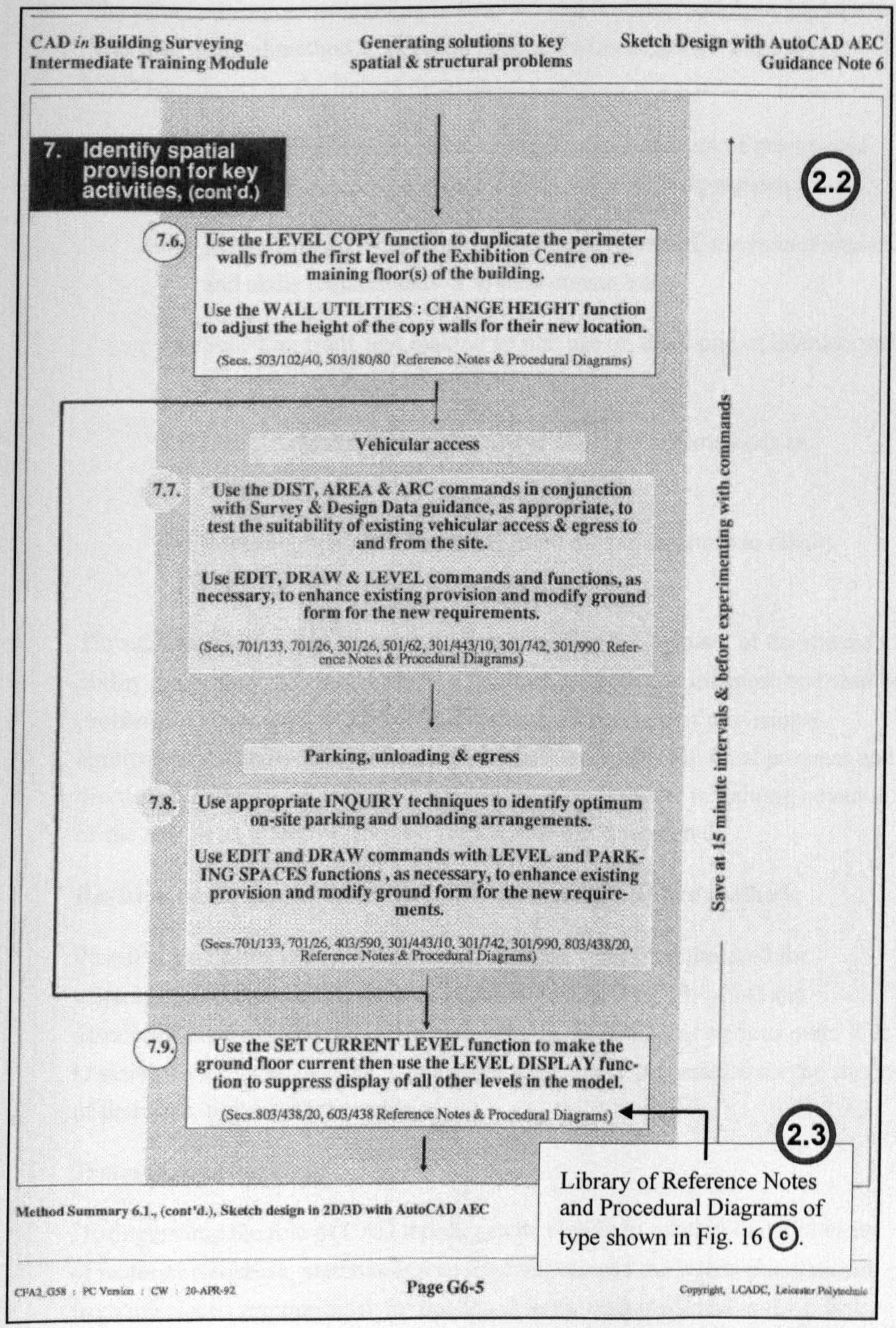


Fig. 28 (cont'd) Instructional method 2, Component 2.2 : Provisional production method

The principal sources of learning in Stages 5 and 6 of the model, as implemented with Instructional method 2, were intended to be investigation and appraisal of CAD techniques by the trainee through:

- Using the software system to implement sufficient of provisional methods to rapidly test their utility for specified purposes.
- Identifying and recording problems encountered, for example time and skills requirements or system constraints.
- Selecting from, and making ad hoc use of, the range of instructional resources provided (Fig. 21, p177).
- Identifying and testing alternative concepts and methods as necessary.
- Revising provisional method summaries in response to results obtained.

Throughout this process of instruction and learning, assessment of the trainee's ability to use the CAD system for the required purposes, to diagnose and resolve problems encountered, and draw implications for revision of provisional application strategies, continued through observation of individual progress and discussion between the instructor and trainee. Similarly the remaining potential of the task as an effective learning vehicle was also monitored.

Revision of the initial alternative instructional model and methods

Practical experiments with Instructional method 2 clarified the need for enhancing initial proposals for an alternative model (Fig. 19, p174) and associated methods for instruction and learning. Additionally various other R & D activities in Phase 2 (Table 5, p43), and particularly preparation for the survey of practices, indicated inadequacies.

Training needs analysis

Distinguishing the role of CAD training more clearly in relation to deficiencies of material resources, methods and equipment relieved the instructional model from misplaced responsibility for dealing directly with problems in the practice other than human performance deficiencies. Doing so, however, necessitated more explicit provision for training needs analysis as shown in Fig. 30.

Attempting to make CAD training more responsive to requirements of the individual workplace and trainee without effective analysis of factors other than human performance deficiency risked inadvertent expectation for instructional solutions to problems with other root causes. The model was consequently enhanced with explicit reference to Romiszowski's (1984) comprehensive schema for resource management and problem solving in the organisation, as discussed on pages 76-78 and summarised in Fig. 11, page 77.

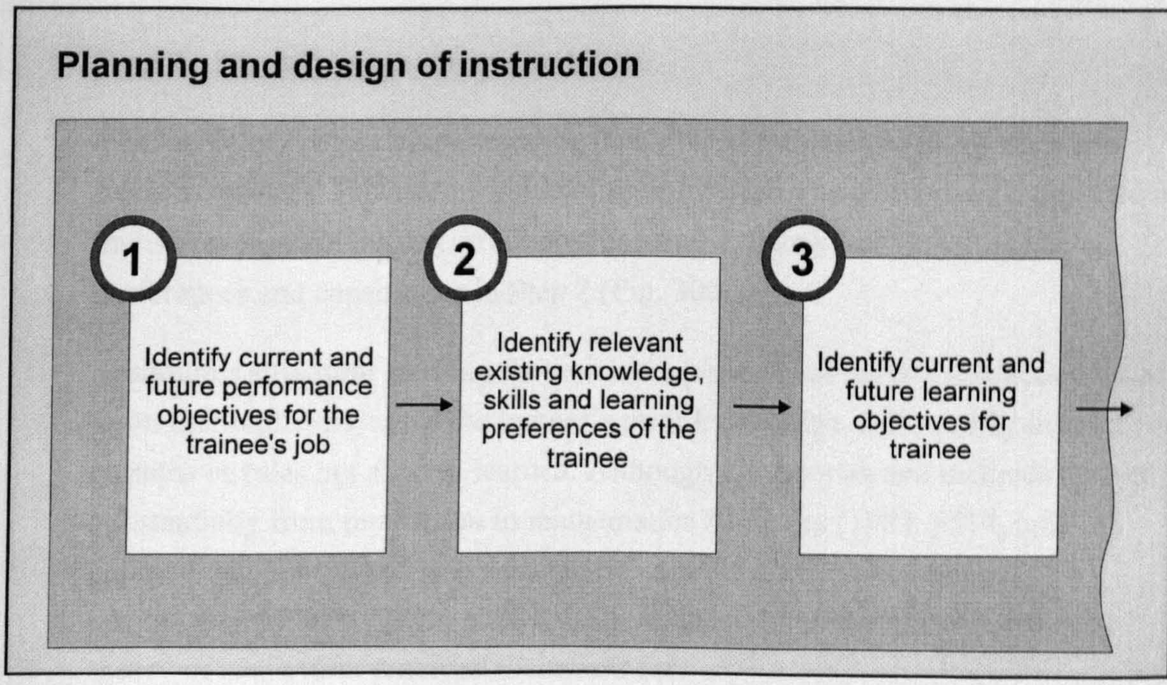


Fig. 30 Initial provision for training needs analysis

Experiments with Instructional method 2 demonstrated substantial deficiencies in the mechanisms intended for individualising instruction. In particular a requirement for the trainee and instructor to engage in ad hoc training needs analysis during training events to ensure a sequence of relevant instruction and learning through Steps 1-6, (Fig. 19, p174), frequently proved impracticable.

Step 1 : Identifying performance objectives

In the revised model current and future performance requirements for using CAD in the specified post of the particular workplace are identified first.

Review of the literature identified many competing theories and alternative practices for corresponding task analysis[1] but little to inform Step 1 of the instructional model and its specific concern with using CAD systems. It was clear, however, that effective analysis in other contexts required considerable time and expertise. In these circumstances the need to establish performance requirements was acknowledge in the model (Fig. 30①, p190) but specification of mechanisms for doing so was deferred pending further investigation of alternatives.

Step 2 : Identifying existing capabilities

Version 1a of the model inadequately recognised the existing knowledge and skills of trainees. Provision for planning and design was consequently adjusted to include evaluation of the current post holder's existing knowledge, learning preferences and capabilities in Step 2 (Fig. 30②).

Scandura's structural learning theory recommended one-to-one instruction based upon thorough analysis of the learner's prior knowledge, followed by instruction in paths or rules not already learned. Although his theories and methods derived substantially from instruction in mathematics Scandura (1983, p214, pp232-3) claimed that his method was particularly suited for use in a computer environment. Landa (1983, p208), meanwhile, claimed that his algo-heuristic theory of instruction provided the means for:

> "Identifying the learning procedures leading to the development in learners of performance algorithms or heuristics (i.e., identifying learner's learning algorithms or heuristics)."

Unfortunately techniques relevant to learning application of CAD systems were not found in the available literature.

Step 3 : Identifying learning objectives

Comparison of the trainee's existing knowledge and abilities, identified in Step 2, with performance requirements of the post allows specification of individualised current and future learning objectives in Step 3 (Fig. 30③). In theory this process

1 For a succinct summary of alternatives see Romiszowski (1984), pp95-119.

would significantly reduce subsequent need, identified by Scandura (1983, p240) in his structural learning theory to:

> "Assume the paths the learner already knows and gradually 'build in' those that he or she does not."

Guidance on identifying learning objectives for training in CAD was sought initially in Gagne's (1970, p1) frequently quoted five learning domains[1]:

1. Verbal information
2. Attitudes
3. Motor skills
4. Intellectual skills
5. Cognitive strategies

In the sense that Gagne's verbal information domain referred to "...a set of directions that can be learned as 'knowledge'..." (Reigeluth 1983, pp190-194) then the ability to assimilate, act upon and give verbal information is important for effective CAD applications. Such ability was not, however, observably a cause of sustained performance problems with users of the technology. At this stage in the research the need to develop appropriate attitudes also appeared of relatively low significance for developing CAD understanding, knowledge and skills, although its relevance was subsequently recognised to a much greater extent in proposals for active learning (pp249-273). Motor skills are clearly important for effective use of a CAD system but classroom observations indicated that deficiencies like poor control of a pointing device are generally easily diagnosed, and rarely cause prolonged difficulties. Of Gagne's five learning domains, therefore, intellectual skills and cognitive strategies, for example in discerning and assimilating CAD concepts and techniques, were considered most relevant for the alternative model. A closer correspondence between published theory and the observed requirements of effective CAD practice was found in Gropper's (1983, p105) classification of learning objectives:

1 See for example Aronson and Briggs (1983, p81).

1. Recalling facts.
2. Defining and illustrating concepts.
3. Giving and applying explanations.
4. Following rules.
5. Solving problems.

Whilst the learning domains of both Gagne and Gropper were relevant, neither provided a clear and complete basis upon which to specify learning objectives for training in CAD.

Provision and use of learning tasks and resources

To a significant extent choice of instructional methods is influenced by the characteristics and combination of media selected, and vice versa. Potential of Stages 1-6 in the initial Instructional model (Version 1a) and associated learning resources (Fig. 19, p174) were reviewed in relation to the extent that Instructional method 2 responded effectively to a range of learning objectives and the existing capabilities and learning preferences of trainees.

Overall only limited success was achieved enabling trainees to individualise learning tasks and learning resources to meet their specific requirements by the methods described for Instructional method 2. Mechanisms designed for this purpose were widely perceived by trainees to add unnecessary difficulty to the assignment. In practice for a high proportion of trainees Instructional method 2, like Instructional method 1, resulted in substantially less development of knowledge and capability by the end of a learning task than its logic suggested. There was, however, anecdotal evidence over a longer period that some trainees were able to trace improved capability for using CAD to their experience with Instructional method 2. Distinguishing between causal factors in specific cases was difficult but observably included:

- Characteristics of the trainee:
    - Previous experience:
        - Knowledge of CAD systems.
        - Knowledge of the application environment.

        - Initial experience with a learning task.
        - Time available for self-directed work on learning tasks.
    - Learning preferences and capabilities.
- Inherent constraints of paper-based learning resources on the design and operation of instructional methods and resources for required purposes (Supplementary Defect 2.5a).

These results raised the significance of achieving effective methods for analysis, planning and design of instruction. In particular, overcoming the deficiencies of prestructured learning tasks and associated resources for general use required analysis of the requirements of specific practices and personnel to be followed by individualised instruction. It would also be necessary to resolve observed constraints on achieving effective self-directed learning. Evident limitations of Instructional method 2 also implied a need for more effective assessment to clarify constraints on learning and to inform remedies.

Learning tasks

Despite contributing substantially to a more rigorous instructional design methodology for individualised learning Ayerst's prescriptions discussed in Section 3.10, pp153-172 proved increasingly inadequate as requirements of an alternative instructional model were refined. In the context of results from research and development at this point in the investigation, application of Step 1.2 (Fig. 13, p154) concluded that Instructional methods 1 and 2 inadequately prepared staff for cost-effective application of CAD system(s) to authentic tasks in a building surveying practice. Step 1.3 identified the most effective alternative in training as directly as possible for the requirements of individual trainees and their practice. The unavoidable implication, considered in discussion of training needs analysis on pages 189-193 was to start the training process with detailed training needs analysis (Fig. 30, p190) followed by individualised instruction and assessment for individualised learning objectives. From Step 1.6, onwards, however, Ayerst's methodology assumes production of an instructional package with content identified in Step 1.5 and routing predefined in Step 4. Consequently where the emerging alternative model prescribed rapid production of an unknown number of short life and highly individualised learning tasks with ad hoc access to appropriate resources, Ayerst's method assumed significantly longer lead times for collective use of a much smaller number of instructional packages over considerably longer periods.

Experiments with Instructional method 2 achieved valid content in dealing with application of CAD throughout the stages of a refurbishment scheme (Defect 2.3). The learning task was authentic but it was also too extensive and perceived by trainees to involve them in functions beyond their individual remit within a project team. Substantial time was required, moreover, to fully utilise the prescribed learning resources and source data. This period exceeded the time allocated to formal training events and trainees were generally unwilling or unable to continue working through a learning task at other times (Defect 2.7, Supplementary defect 2.9a).

Trainees were also predominantly unwilling or unable to individualise the base learning task in Instructional method 2 by selecting and concentrating on those processes of particular relevance to them and their role in the workplace. Most chose instead to work a linear route through provisional method summaries, giving equal weight to each component and making little attempt to review and revise the sequence. Although substantially more willingness and ability was evident for investigating software functionality than for individualising a learning task by selection from, and review of, method summaries many trainees were frustrated in their attempts by a limited capacity for independent inquiry and clearly needed to develop more effective methods (Supplementary defect 2.7a).

It appeared that individualised instruction would remain problematic whilst paper was the primary medium for delivering learning tasks. The high costs of developing such resources in terms of staff and lead time tended to preoccupy training providers and reduce their capacity for training needs analysis. Inherent constraints on the format and use of such learning tasks substantially reduced the scope for responding with effective individualised instruction to the training needs analysis which was undertaken (Supplementary defect 2.5a).

In the absence of a more comprehensive instructional model inadequacies in the design, production and use of paper-based, step-by-step learning tasks and resources would be underestimated. It was clear that modifications were needed to the alternative instructional model in order to deliver individualised content. (Defect 2.9a)

Whilst the principles of both Merrill and Scandura addressed fundamental inadequacies found at the core of conventional training for CAD, neither made prescriptions that could be readily assimilated in the alternative model. Although Scandura proposed individualised instruction his examples were mainly drawn from the teaching of mathematics and little was found to directly inform methods for training in CAD[1]. Many trainees displayed limited inherent capacity for experimentation and discovery learning with the CAD software. Concurrently they were often unwilling or unable to respond effectively to opportunities and cues in hard copy documentation for self-directed investigation of concepts and techniques.

Scandura's structural learning theory emphasises selection of higher order rules wherever possible to reduce the amount of content to be taught. It stresses

1 Scandura was one of a number of instructional theorists who structured and expressed their ideas in ways which were difficult to assimilate.

simple-to-complex sequencing of instruction and allowance for growth of knowledge as learners interact dynamically with a changing teaching environment. Diagnosis and instructional prescriptions begin with structural analysis in which rules are broken down into atomic components. (Scandura, 1983, p217; pp223-4). In this context it was necessary to moderate the demands of a learning task in response to capabilities of the individual trainee at any given point in his or her development. Effective mechanisms for moderation were anticipated through monitoring, judgment and intervention of the instructor, trainee, workplace supervisor and colleagues, and through interaction between them.

Version 1a of the alternative instructional model assumed that a learning task would continue as a meaningful activity until its logical conclusion. Consequently no provision was made for the trainee to take an early exit route once potential for further learning had been depleted. Experiments with Instructional method 2 had shown, however, that just as initial perception by trainees of low relevance in the content of a learning task could reduce the effectiveness of learning based upon it, they could also come to perceive little remaining purpose in continuing to its scheduled completion (Fig. 34⑩, p206). The model was therefore modified so that trainees could abandon a learning task once its potential for developing additional understanding, knowledge and practical ability had effectively been achieved. Like various other developments proposed for the model, specific mechanisms for implementing this proposal were not apparent at this stage of the research programme.

Results from research and development in Phase 2 were also questioning whether individualised instruction, learning tasks and resources have necessarily to be planned and structured in advance, or if techniques might instead be found and developed for a more responsive, ad hoc methodology. Potential means of providing for ad hoc learning activity were consequently considered in subsequent versions of the model.

Identifying and implementing solutions

Initial tests of Stage 5 in class requiring trainees to identify an optimal solution to a specified CAD task produced disappointing results. In most cases the problem set required more explanation than had been anticipated. Many trainees also required considerable reassurance that a guided discovery approach to learning was worthwhile before applying themselves to achieving solutions. Even after explanation of the task and its intended benefits, few trainees considered that they had the necessary knowledge and ability, specifically for investigating an optimal solution.

Experiments with Instructional method 2 had in many cases overestimated the inherent ability of trainees to direct their own learning of CAD concepts and techniques. They also extensively failed to create and exploit opportunities for undertaking and practicing relevant processes. These problems were apparent firstly through overdemanding requirements on trainees to find optimal solutions and, secondly, through inadequate scope for self-direction in the learning mechanisms provided.

Experiments with Instructional methods 1 and 2 involved two extremes. Pre-defined, step-by-step learning tasks tested in Instructional method 1 displayed a range of characteristics discussed in Section 3.10 (pp153-172), which limited the trainee's progress and development. By contrast, Instructional method 2 proved demanding by requiring trainees to find optimal solutions to authentic tasks in Stages 2-5. Expecting trainees to find optimal solutions to CAD applications frequently proved challenging to the point of being counterproductive. In this respect Instructional method 2 overcompensated for the inadequacy identified in Instructional method 1.

Requiring progress by trial and error within a framework of specifications and learning resources was found to result in significant development of knowledge and ability but only for a small proportion of trainees. In many more cases the learning experience rapidly became a succession of impasses needing intervention from the instructor to resolve. In either case the intended method was observed to be unnecessarily costly in terms of learning time and frustration for trainees. It was also found to deliver an inadequate return on analysis, planning, design and production effort by the instructional designer and training provider.

A first step in developing the benefits for instruction and learning of representing use of CAD as a problem solving activity was by responding to Defects 2.11 and 2.7 with moderated expectations that required trainees to identify adequate rather than optimal solutions.

Subsequent observation of CAD-skilled practitioners indicated that self-directed learning for use of systems occurred at different levels. Expecting trainees to respond directly at a high level without instruction in corresponding techniques, or allowing sufficient time for their assimilation, was unrealistic and often counterproductive.

Experiments with Instructional method 2 had also demonstrated the need to either communicate and confirm the purpose of developing capabilities for more effectively solving problems with CAD applications, or to achieve more relevant tasks per se. Initial proposals for clarifying the content of learning tasks were therefore extended in Version 1d of the model to include checks on the trainee's understanding of its relevance (Fig. 31⑤d, p200).

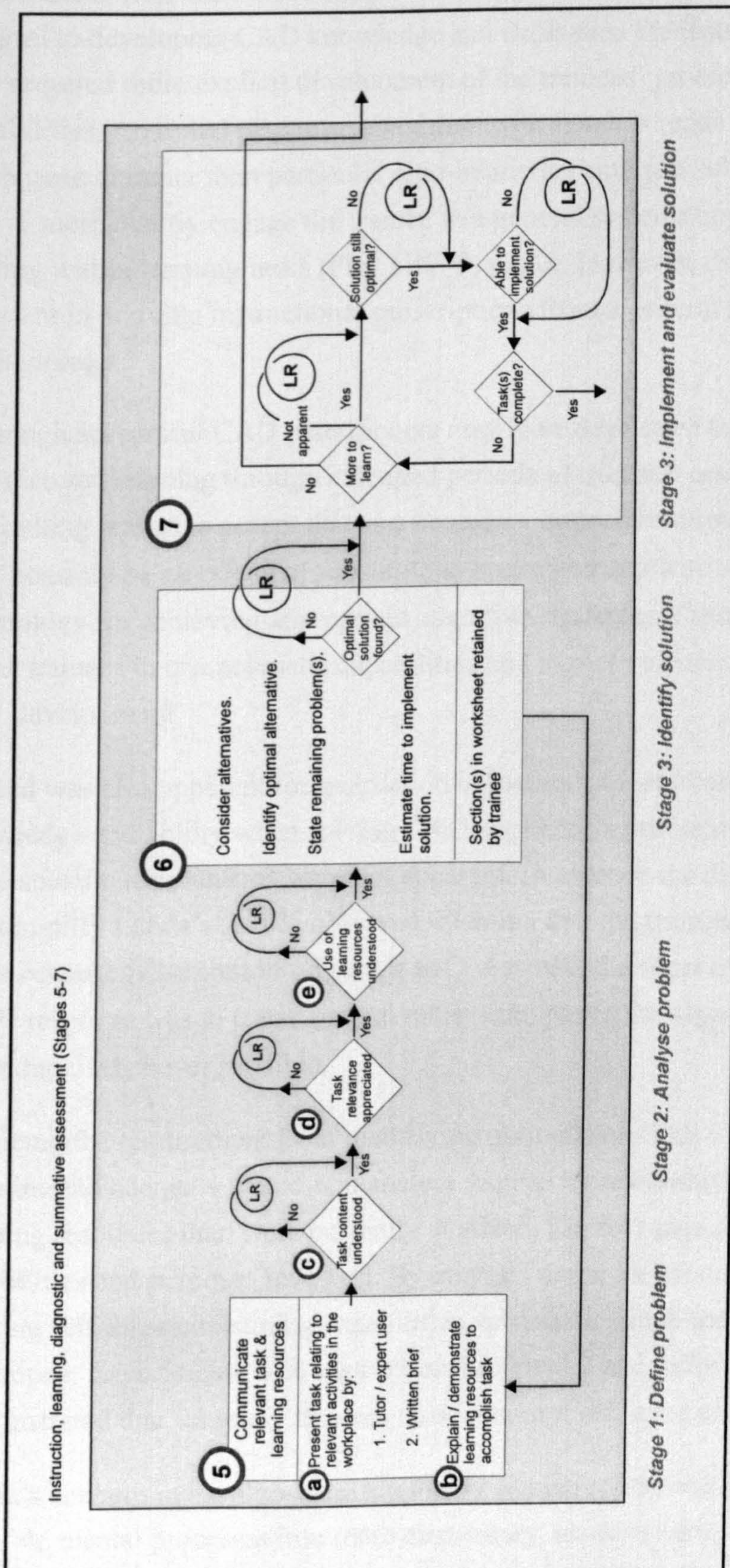


Fig. 31 Use of a general systems methodology for problem solving in learning tasks

Experiments with Instructional method 2 suggested that if problem solving was integral to developing CAD knowledge and skills then the instructional process also required more explicit development of the trainees' problem solving capabilities. An initial response, consistent with Landa's recommendation to teach general rather than particular algo-heuristic principles wherever possible, was to more overtly engage the trainee in a general systems approach to problem solving within learning tasks (Fig. 31⑤-⑦, p200). However, difficulties became apparent in deriving instructional prescriptions from a general systems methodology.

Although successful CAD practitioners may have developed their capacity for self-directed learning through extended periods of trial and error there was no compelling reason to accept this as a necessary or preferred route. Although there may possibly be no effective substitute to prolonged application of the technology for achieving appropriate cognitive strategies it should be possible to direct trainees in characteristic capabilities and to more efficient methods for their development.

A need was also apparent for instruction in methods to overcome inadequate knowledge and ability when solving CAD application problems, although at this stage specific mechanisms were not apparent. In essence the difficulty appeared to exemplify Landa's (1983) observed dilemma that the trainee "...couldn't figure it out because [s]he couldn't figure it out". An essential tenet of Landa's (1983, p203) response was to teach general rather than particular algo-heuristic procedures whenever possible.

Reducing the requirement from identifying optimal solutions to finding ones that were instead adequate would nonetheless require more effective and accessible learning resources than were currently available for the range of trainee's capabilities and purposes involved. By contrast the model assumed adequate existing self-directed learning capabilities, or time in which they could be developed. Experiments with Instructional method 2 had unfortunately demonstrated that for many trainees these assumptions were unrealistic.

Landa's concern in his algo-heuristic theory of instruction was with clarifying invisible mental processes into more elementary, unobservable, cognitive operations that could be unambiguously executed by learners in the course of learning and performance, and reliably produced by teachers in the course of instruction. Review of the format and use of learning resources for Instructional method 1 in the context of Landa's advice (1983) for achieving command of overall procedures suggested continuing potential of step-by-step instructions for this purpose.

Methods were needed for reconciling the tendency of trainees to find predefined learning tasks of the type reported on pages 153-172 tedious in use and unnecessarily delaying application of CAD to authentic tasks, with finding and applying solutions to challenging problems beyond their current capability in Stages 2-6 of Instructional method 2, as discussed on pages 184-189. Landa (1983, p194) recommended identifying an optimum relationship between teaching ready-made algo-heuristic procedures and requiring trainees to discover their own.

Resources for instruction and learning

Various problems with Instructional method 1 had derived from the central role of step-by-step, paper-based learning tasks. High production costs coincided with trainees perceiving limited relevance in the content whilst experiencing a deferral of authentic applications and transfer of learning. Other significant aspects were not adequately addressed including development of self-directed learning capabilities (Defect 2.5a). Indeed, worksheets of the type introduced and tested arguably encouraged a dependent approach to learning.

The amount of reading involved for Instructional method 2 generally disinclined trainees to cross-reference Method Summaries with the library of paper-based Reference Notes and Procedural Diagrams. Notable exceptions occurred where the instructional sequence related very closely to the specific current requirement, or when no easier solution route was more readily available. Comparisons were apparent with step-by-step instructions for self-assembly products where the user follows very precise sequences to achieve a result but without the activity necessarily resulting in greater understanding of the core principles involved unless a specific effort is made to identify and assimilate them. Effective assimilation of core principles is more reliably achieved through opportunities and willingness for reapplying generic principles to new requirements within an appropriate time scale.

Substantial difficulties were also encountered with Instructional method 2 in reconciling strategic advice and guidance in general principles with step-by-step procedures and instruction, experimentation and discovery learning (Defects 2.7, 2.8, 2.11). Removal of site and building specific content from Method Summaries to achieve general applicability left many trainees in difficulty when attempting to follow and apply the guidance contained (Defect 2.5). This result presented a dilemma because Instructional method 1 had shown that inclusion of specific content in learning resources significantly increased development and production costs whilst limiting prospects for the trainee transferring concepts and techniques to application with other data.

Classifying the trainee's learning algorithms and heuristics in Step 2 (Fig. 30, p190) also implied provision of a correspondingly wider range of learning methods and resources than had conventionally been used in CAD training. Provision for variations in self-directed learning capabilities and preferences needed further consideration (Defect 2.7a). Similarly, provision for enhancing the self-directed learning capacity of individual trainees required further investigation.

The developing model variously indicated, therefore, a need for alternative forms of learning resource and mechanisms for their use. An instructor with expert knowledge of the CAD system and appropriate instructional capabilities, however, retained a central role amongst these resources. Sustaining dual expertise in a context of rapid software development, extending use of CAD, and innovations in methods for instruction and learning was a significant problem that would need addressing. As Landa (1983, p59) observed:

> "It is evident that in order to carry out any instructional activity to achieve a goal, a teacher should know a prescription (algorithmic or nonalgorithmic) for this activity and / or have command of a system of instructional actions that would lead to the achievement of the goal."

Experiments with Instructional method 2 served to clarify the nature of instructional requirements and corresponding constraints. In this context it could be seen that the instructional resources developed for Method 2 had become more complex in use but without corresponding potential to effectively address significant learning issues. Whilst the need to provide a range of learning resources for ad hoc use during a learning task was acknowledged some potential disparities had also become apparent. In particular work was required to reconcile the actual availability of learning resources and self-directed learning capabilities of the trainee. The instructor would also be required to manage potential mismatches of this type during training events. Setting the role of paper-based, pre-structured learning tasks in the wider context of alternative methods for instruction and learning rectified the apparent but misconceived need for comprehensive, paper-based documentation. Simpler formats for more limited purposes had become both acceptable and feasible.

Testing transferability of knowledge, understanding and practical ability

Difficulties were experienced assessing the extent to which developments in Instructional methods 1 and 2 improved the transferability of knowledge and practical abilities to similar tasks with different data in the workplace. The principal cause of such difficulty was the effective absence of formative and summative assessment in the training process. This omission was, however, consistent with the majority of conventional training practice for CAD. Mechanisms recommended for addressing the gap in response to experiments with Instructional methods 1 and 2, and with evolution of Versions 1a-d of the alternative instructional model, are shown in Fig. 33 on page 205.

The initial model shown in Fig. 19 (p174) had assumed like most contemporaneous commercial training for built environment applications of CAD that completion of the prescribed practical work during formal training events would necessarily result in an acceptable level of new understanding, knowledge and practical abilities, readily applicable to authentic tasks in the workplace. In the case of the alternative model this assumption was somewhat more justified because it required that the content of learning tasks was relevant to activities in the workplace. Nonetheless the absence of summative assessment was a significant inadequacy and the model was extended to include end testing of the trainee's ability to achieve performance objectives with a comparable new task. The implication for diagnostic and formative assessment in Version 1d of the alternative model was that it should be achieved extensively through ad hoc interaction between the instructor, workplace supervisor, colleagues and the trainee. Such developments would be consistent with the individualisation of instruction and learning by a more ad hoc process.

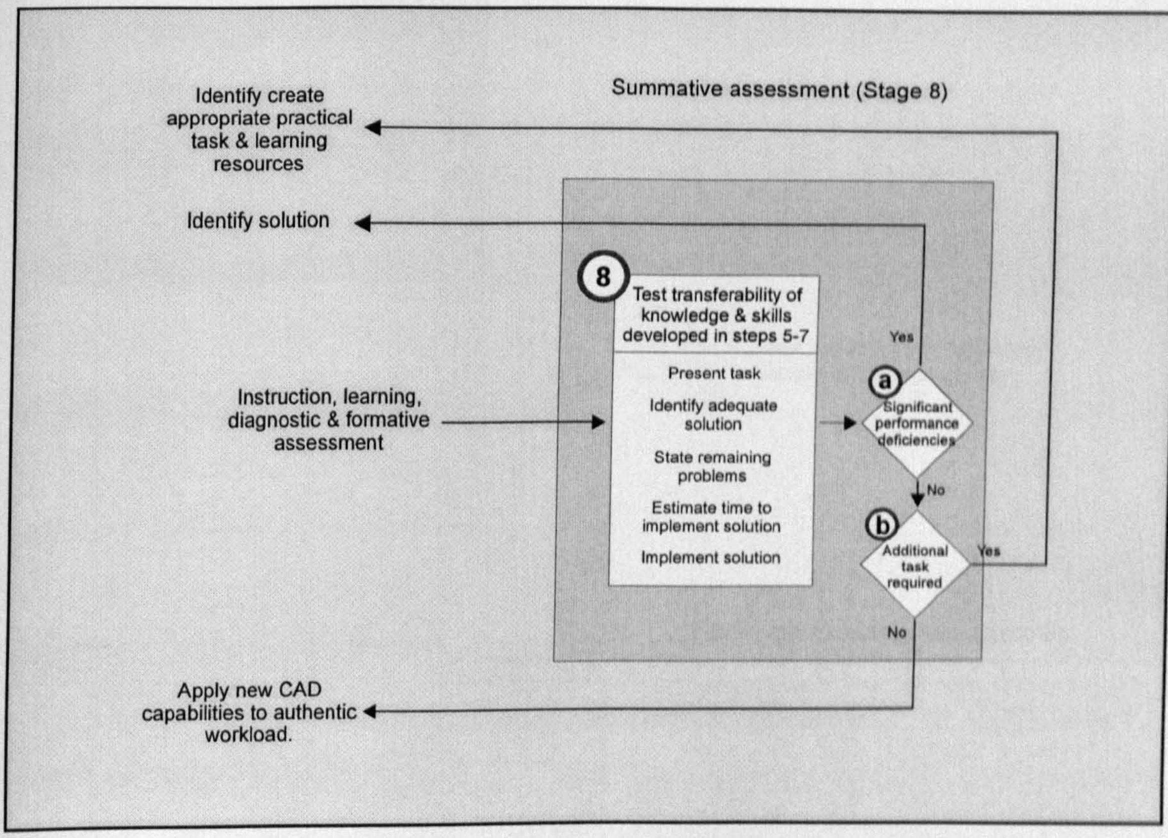


Fig. 33 Provision for summative assessment in Version 1d of the alternative instructional model.

Revised alternative instructional model and methods

Fig. 34 (p206) shows the schematic for an alternative instructional model revised at the end of R & D Phase 2 as Version 1d to incorporate proposals discussed on pages 189-205. Version 1d of the model included provision for:

- Variations between a trainee's existing knowledge and experience.
- Individualised performance and learning objectives, and learning tasks.
- A range of resources for instruction and learning, and guidance on how to individualise their use.

Need for further research and development

R & D Phases 1 and 2 had addressed Defect categories 1 and 2 described on pages 135-146. Progress had been informed substantially through experiences of the AutoCAD and AEC Authorised Training Centre at De Montfort University (1991-3), and through contributing to the City and Guilds of London Authoring group (1992-3). By the end of this part of the research programme significant progress had been made with an enhanced methods for training in CAD, as evidenced in success with the IBM Partnership Award in 1993. It was clear by the end of R & D Phase 2, moreover, that an iterative development process needed sustaining to achieve further enhancements. Subsequent development of the model and methods would require parallel and mutually informing investigation of instructional theory and testing of alternative methods through practical experiments.

Constraints

Research and development up to this point, and the foci identified for subsequent investigations, clearly implied the need for substantial changes in conventional perceptions of, and practices for CAD training. However, the alternative model required significant further development in order to specify what changes were required. Moreover, although investigations to date had suggested that effective alternative instructional methods should combine hard copy, computer-based, interpersonal and self-directed components, specific techniques and an optimal mix had yet to be identified. As a result considerably less scope existed for integrating further development of the instructional model and methods within CAD training for building surveying students and clients of Leicester CAD Centre at DMU than had been possible to date, for example with Instructional methods 1 and 2 (Defect 1).

Landa (1983) amongst others rationalised the limitations placed by resources on the achievable level of individualisation and adaptability of instruction. Indeed, resource limitations restricted opportunities for piloting an increasingly individualised and adaptive model with building surveying students at De Montfort University and clients of the Leicester CAD Centre. Concurrently, Autodesk's quality assurance initiatives to raise standards of CAD training by regulation of its approved training centres was significantly reducing opportunities for prototyping alternative models and methods in commercial training at the Leicester AutoCAD Authorised Training Centre. There was consequently substantial scope for conflict between commercial provision of CAD training and researching and developing alternative models and methods. In particular the practicalities of producing learning resources to service commercial training were at variance with the sustained analysis, experimentation and testing required to research and develop alternatives (Defects 1.2a, 2.2, 2.10).

Restrictive Authorised Training Centre (ATC) policy left insufficient opportunities for further research and development to deal effectively with the inadequacies in training that had prompted Autodesk's attempts to raise standards through regulation. There was consequently less involvement with Autodesk ATCs in the remainder of the research programme.

An iterative process of research and development based on other activities from Table 5 (p43) would be necessary in the absence of directly relevant or sufficiently complete theories of instruction and learning. The limitations observed for paper-based learning tasks and apparent lack of specific guidance on practicable alternatives suggested selective reverse engineering to infer mechanisms from those propositions that had been articulated by various theorists.

Foci for subsequent research and development

Although the case for individualised content and instruction was clear, effective and viable methods to achieve them were not obvious (Defect 2.3a). Results from investigating methods for individualising task-based learning in R & D Phase 2 consequently focused subsequent research and development upon identifying an enhanced instructional model and associated methods in terms of:

1. An adaptive training shell, independent of CAD system origin and software release for responding to the authentic requirements and constraints of individual workplaces and trainees.

2. Effective methods for:

   a) Training needs analysis, planning and design.

   b) Production and use of individualised learning tasks and resources, including developing the capabilities of trainees for self-directed learning.
   Essential requirements for different levels of self-directed learning of CAD needed investigating in conjunction with more efficient means of developing required capabilities. Methods were also required for identifying the content of learning tasks, associated resources, and structures to optimise their use by trainees collectively displaying a range of self-directed learning capabilities.

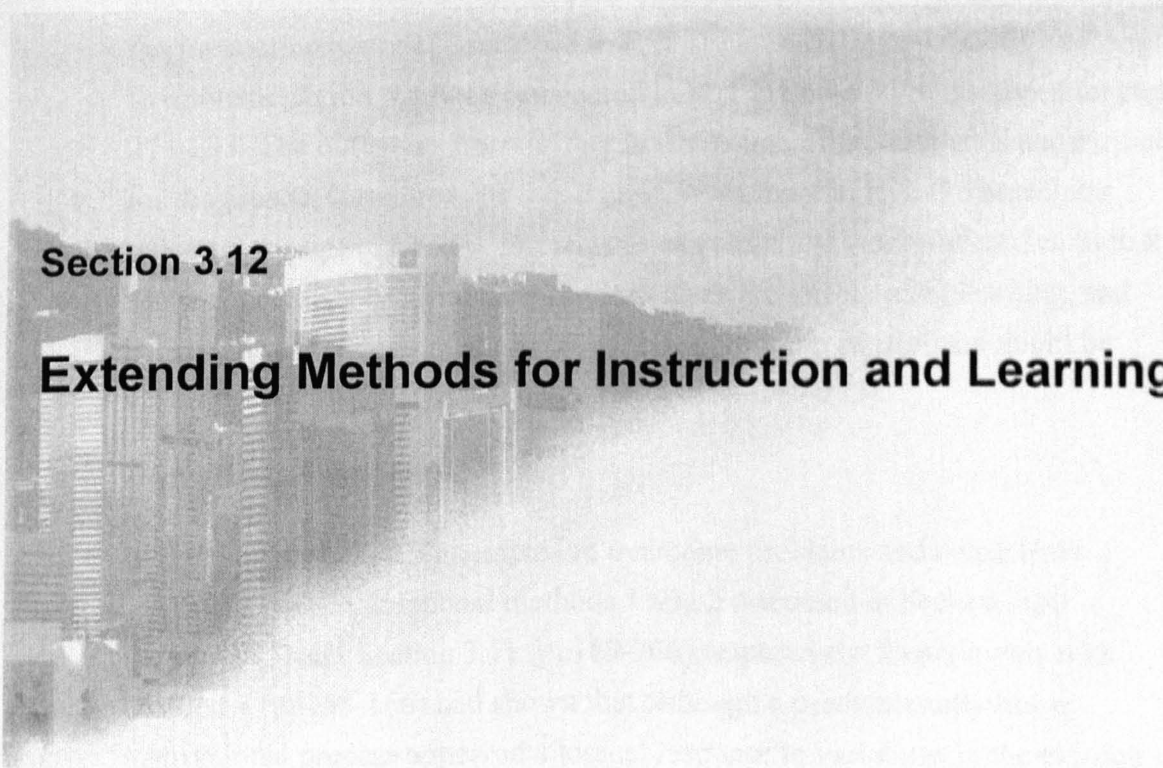
   c) Diagnostic, formative and summative assessment.
   In particular to clarify the extent to which suitable mechanisms could be found, including observation and discussion in class, to test:

      - Understanding of the content for a task and its relevance.

      - Awareness of relevant learning resources and ability for using them.

      - Availability and adequacy of solutions to the CAD task and sub-tasks.

      - Residual learning potential of the task.



Section 3.12

Extending Methods for Instruction and Learning

3.12. Extending methods for instruction and learning

Section 3.12 (pp210-292) considers results from work undertaken in R & D Phase 3 (Table 4, p40) to develop the alternative instructional model and methods in response to research foci identified at the end of R & D Phase 2 (p209). The emphasis of pages 210-292 is upon identifying effective methods for production and use of individualised learning tasks and resources (R & D focus 2b), including developing the trainee's capacity for self-directed learning. Discussion begins with consideration of a hybrid Instructional method 3, combining interpersonal and paper-based methods with use of proprietary on-line resources, in response to results reported on pages 189-208 of Section 3.11. Subsequent discussion concerns the prototyping of various computer-based resources to address high production costs and moderate problems of implementing the alternative model with individualised paper-based resources and interpersonal instruction. Results from concurrent work to address defects of the instructional model developed in R & D Phase 2 (Fig. 34, p206), and respond to implementation methods considered in R & D Phase 3 are discussed on pages 274-283. The outcomes from further investigation of requirements and methods for diagnostic, formative and summative assessment in R & D Phase 3 are reported on pages 283-289. For reasons of continuity, work undertaken in R & D Phase 5 to clarify requirements of CAD users for self-directed learning, and investigate alternative methods by which appropriate capabilities might be developed, is also discussed in Section 3.12 (pp249-273).

Instructional method 3

Instructional method 3 attempted to overcome problems and constraints identified with Instructional methods 1 and 2 discussed in Section 3.10 (pp166-172) and Section 3.11 (pp189-206) respectively. Experiments with Method 1 (pp158-166) had shown that although a predominantly linear instructional process appeared a logical response to variations in the existing CAD experience of trainees, significant shortcomings were experienced with its implementation. These difficulties included limited utility of the mechanisms intended to accommodate variations in existing CAD capabilities, and the resourcing implications of individualising learning tasks for specific workplaces. Experiments with Instructional method 2 (pp179-189) had demonstrated that providing trainees with a range of learning resources, and opportunities for guided discovery learning with authentic tasks, was problematic for predominantly different reasons. Amongst such constraints was the impracticability of ad hoc training needs analysis during training events, time-consuming trial and error work with learning tasks, and the explicit requirement to develop the self-directed learning capabilities of trainees. These results suggested potential benefits from synthesising the more productive aspects from both methods. At the same time, because of problems experienced, it had become necessary to acknowledge paper as an inherently constraining medium for either pre-structuring individualised instruction or providing components for the trainee to individualise by selective use. These constraints on production and use of learning resources were emphasised by the progressively interactive and responsive interfaces of CAD systems themselves. Instructional method 3 experimented with identifying a format for learning tasks that was consistent with these developments and could also be used effectively with varying complexities of content by trainees collectively demonstrating a wide range of CAD experience.

Principal components and methods

Instructional method 3 combined interpersonal and paper-based methods with limited use of proprietary online help systems. Principal components for the method, shown in Fig. 35[1], p212, comprised of formal presentations, planned and ad hoc demonstrations, with practical work by trainees to accomplish paper-based learning tasks, (Figs. 36, p213 and 37, p214).

In response to the demanding modus operandi of Instructional method 2, requirements of trainees undertaking a learning task were variously reduced (Fig. 36, p213). The need to interpret a brief and corresponding specification for output data were omitted. Similarly, the expectation for trainees to improve on provisional Method Summaries was discontinued in response to results from experimental use of Method 2, (pp198-202). Fewer and simpler learning resources with more consolidated graphical content were developed to help reduce the time and effort needed to complete a learning task.

1 Instructional method 3 was first tested in a commercial training programme for architects, as evident from Figs. 35-37, before being used with undergraduate building surveyors (Figs 40-41).

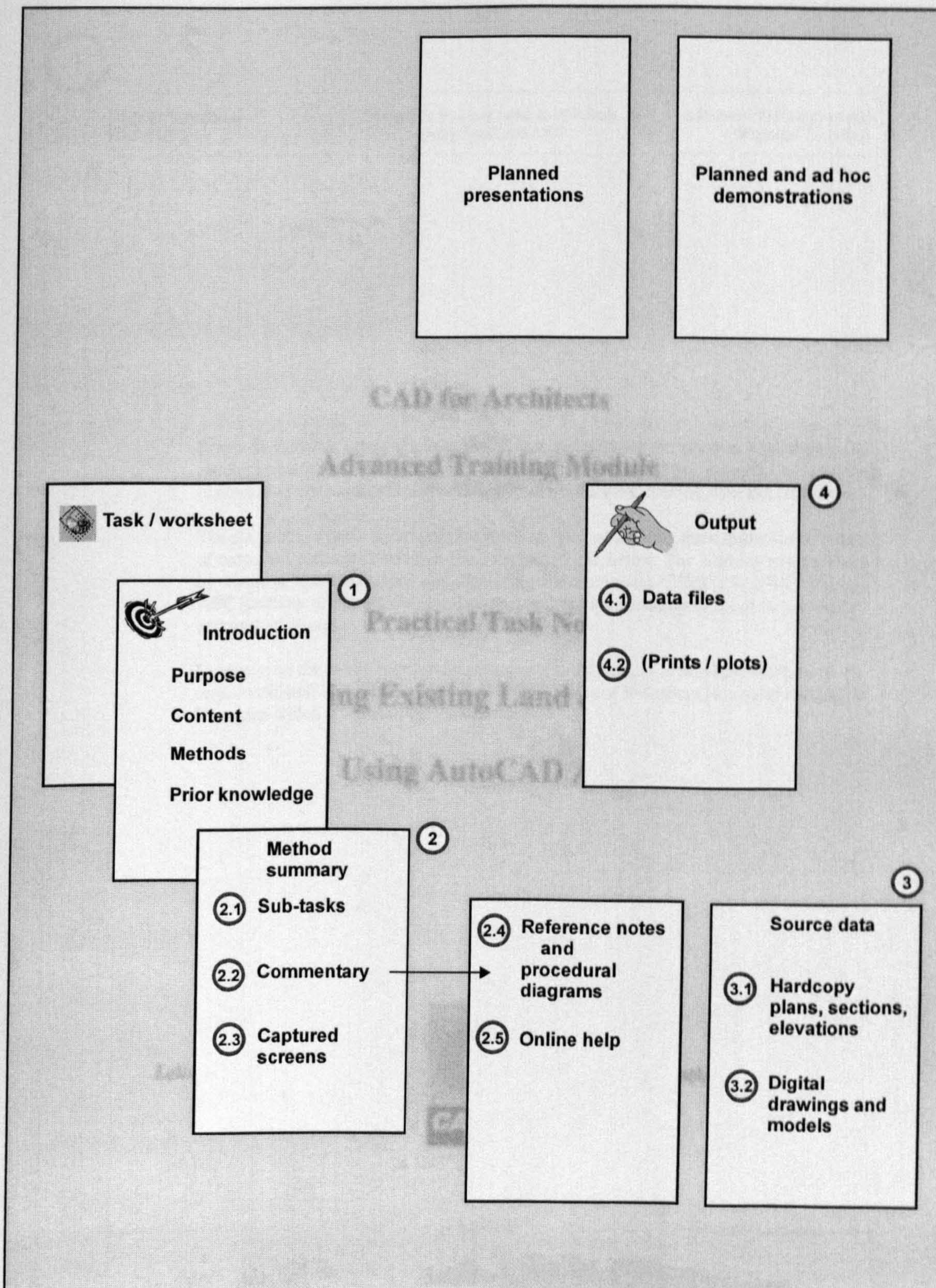


Fig. 35 Instructional method 3: Overview of components

1

CAD for Architects
CADFA3

Modelling Existing Land & Buildings
Using AutoCAD AEC

Advanced Training Module
Practical Task No.1

INTRODUCTION

Practical Task No.1 provides a hands-on demonstration of the essential capabilities and modus operandi of AutoCAD AEC, the Architectural, Engineering and Construction extension to the AutoCAD software system for modelling existing sites and structures.

The sequence of tasks which follows is based upon an existing three dimensional model of industrial premises, shown in Fig.1 on page T1-2, below. The working session starts by entering AutoCAD AEC and displaying the site model CFA3_T1S.DWG. Various AEC functions are then utilised to construct and manipulate components of the upper floor and roof structure.

Guidance on the use of appropriate commands and functions is provided in the commentary. Additional information is available in the series of Reference Notes and Procedural Diagrams which accompanies this worksheet.

CFA3_T11 : CW : 09-NOV-92 **Page T1-1**

Fig. 36 Instructional method 3, Component 1: Statement of objectives, content and methods

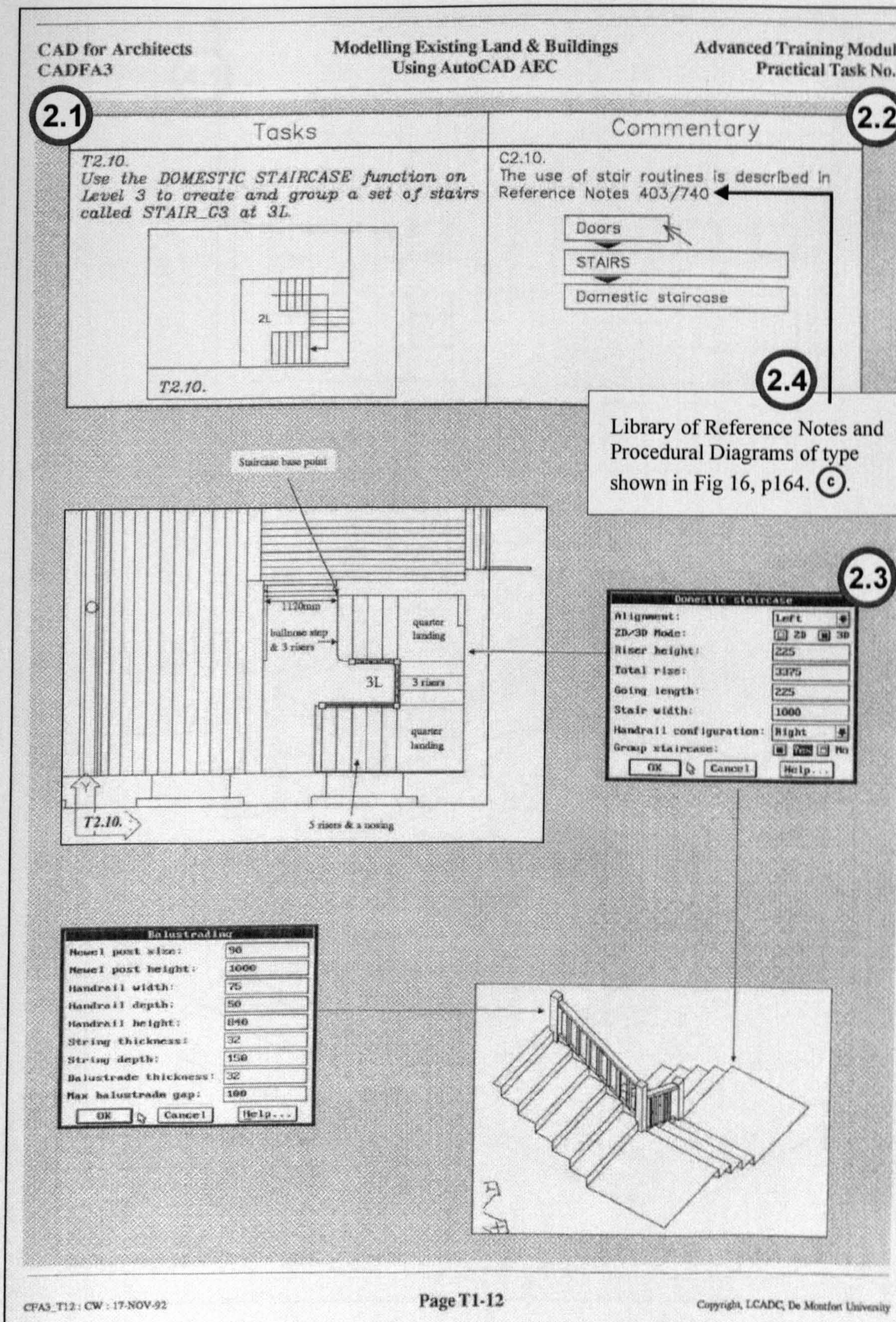


Fig. 37 Instructional method 3, Component 2: Method summary

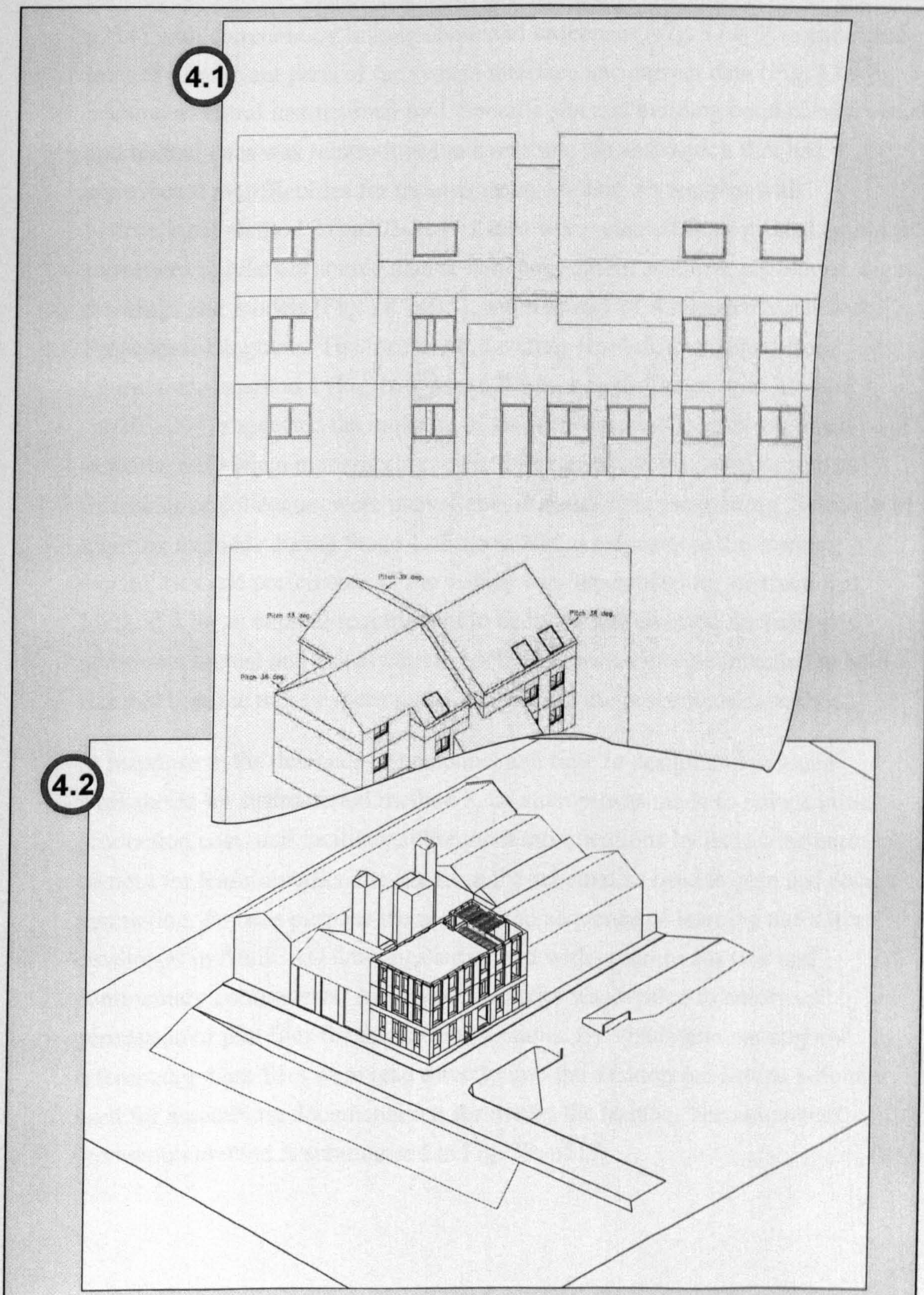


Fig. 38 Instructional method 3 source data: Hard copy plans, sections and elevations (4.1), Digital drawings and models (4.2)

Method summaries, comprising short descriptions of sub-tasks (Fig. 37 (2.1), p214) with commentary linking command sequences (Fig. 37 (2.2)) to annotated images of relevant parts of the system interface and current data (Fig. 37 (2.3)), became a central instructional tool. Specific site and building content with visual and textual cues was reintroduced to overcome the abstraction that had contributed to difficulties for trainees using Method Summaries with Instructional method 2 (pp203-204). Links were retained from printed command sequences to relevant source data in hard copy plans, sections, elevations, digital drawings and models (Fig. 38, p215), and a library of Reference Notes and Procedural Diagrams. The format for the latter was left unchanged from Instructional method 1 (Fig.16 (2.1c), p163), since experiments with Method 2, (pp203-204) suggested the majority of trainees were inclined to use this type of resource only when more direct routes, for example ad hoc advice from an instructor or colleague, were unavailable or needed supplementing. Selection of learning methods during Stage 1 of the model in response to the learning capabilities and preferences of the trainee was superseded for Instructional Method 3 by an explicit requirement to be more self-directed. Inclusion of additional textual and visual cues in Method Summaries was intended to help trainees become more experimental in applying the procedures described.

In response to the demands of personnel and time to design and produce worksheets for Instructional method 2, an attempt was made to reduce initial production costs and facilitate subsequent modifications by extracting core content for learning tasks directly from the schematics used to plan and design instruction. For this purpose the content and sequence of learning tasks were developed in AutoCAD drawings structured with columns for task and commentary components. An AutoCAD script was written to automate generation of plot files for the various sections. By systematic naming and referencing these files were read directly into the desktop publishing software used for assembling documentation for use by the trainee. The automated production method is summarised in Fig. 39, p217.

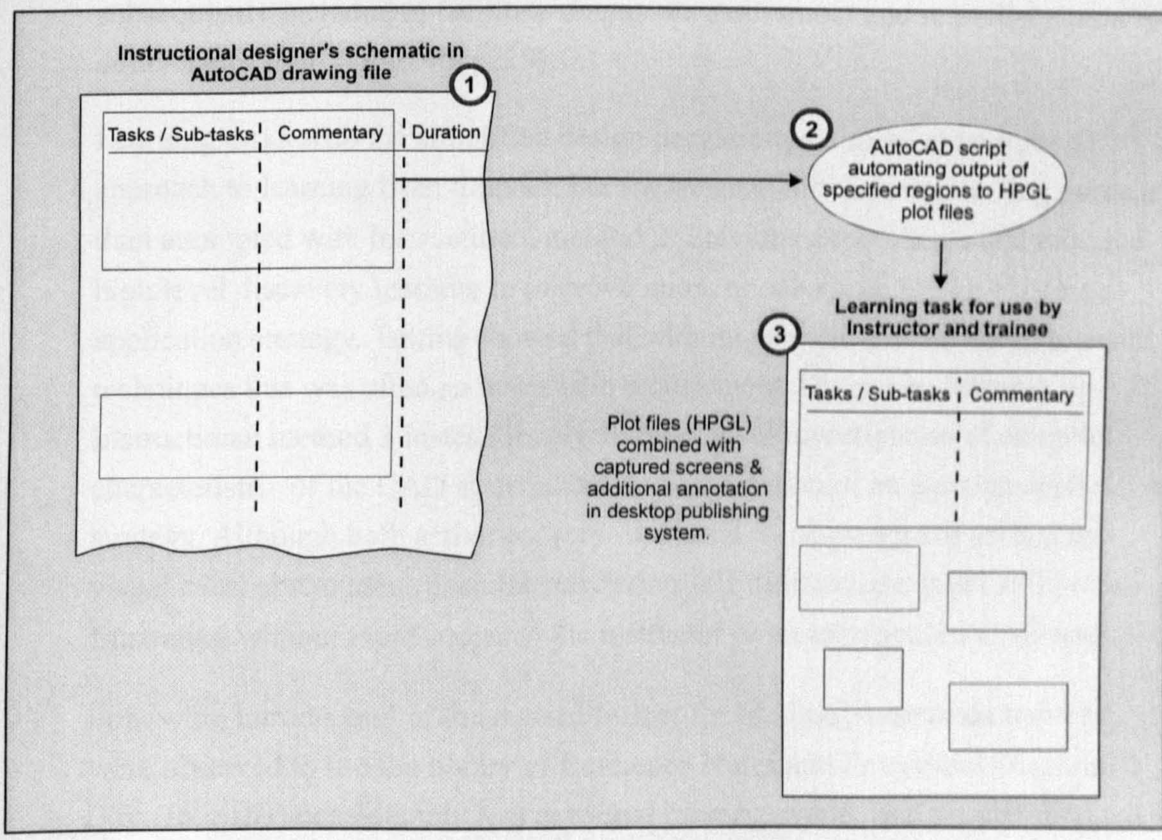


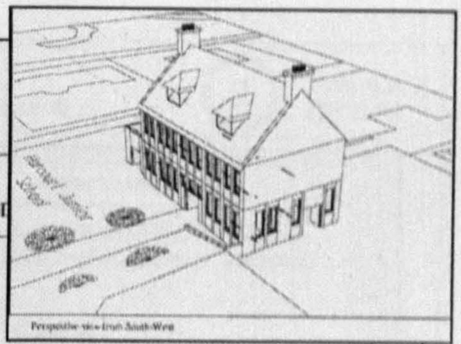
Fig. 39 Automating production of paper-based learning tasks

Results of experiments with instructional method 3

Synthesising the most productive features from Instructional methods 1 and 2 resulted in essentially linear learning tasks, but which were characterised by considerably reduced textual descriptions and substantially more interaction with the CAD system. Method summaries redesigned with increased graphical content (Fig. 37, p214) were observably more usable in class by trainees with previous experience of CAD than those tested for Instructional method 2 (Fig. 27, p186). Juxtaposition of text and diagrammatic descriptions of requirements, command sequences, dialogue boxes and captured screens (Fig. 37, p214) achieved a layout for task sheets that was more compatible with the operational environment of the CAD system than in previous documentation. However, the inherent nature of paper-based task sheets still required a willingness and ability of the trainee to initiate and sustain a dialogue with the CAD software and learning resources indicated. Beginners with CAD commonly needed coaching in use of the documentation, and some remained uncomfortable with the thought processes and practical activities required of them. Clearer statements of the knowledge and practical abilities required on commencing a learning task were subsequently included to facilitate diagnostic assessment and remedial action for deficiencies found (Fig. 40, p219).

Learning tasks with the simplified design necessitated a more experimental approach to learning from trainees, but for substantially less demanding purposes than attempted with Instructional method 2. Previous experiments had required high level discovery learning to improve upon, or substitute for, an existing application strategy. Testing showed that without specific instruction in relevant techniques this was often an unrealistic requirement. Discovery learning in Instructional method 3 instead involved lower level investigation of essential characteristics of the CAD system, and implementation of an existing application strategy. Although both activities were supported by sequences of textual and visual cues, obstructions encountered during self-directed use could still prove frustrating without rapid access to the instructor or an experienced CAD user.

Following introduction of the revised format for Method Summaries trainees were observed to use the library of Reference Notes and Procedural Diagrams (Fig. 16, p163) considerably less in formal training events, and for self-directed learning. The substantial overhead of maintaining the library for a small and declining uptake was difficult to justify and relevant cross-references were removed from learning tasks. Cues for the command sequences required in the CAD system to display relevant sections from its on line help resources were substituted instead to encourage self-directed use of proprietary learning resources by trainees (Fig. 41, p220). Unfortunately the utility of AutoCAD on line help files was limited at the time of the experiments and tended to dissuade trainees from including regular use of such sources in their learning methods. An interesting insight was also gained as a result of these changes into the psychology of some trainees. Despite compelling evidence of declining use of step-by-step instructions a surprising proportion of trainees expressed concern at withdrawal of the Reference Notes and Procedural Diagrams, perceiving it as a significant constraint on their progress with learning tasks.



IT & Studio
Using AutoCAD AEC

Learning Task 1
Modifying Existing Land & Buildings in 3

INTRODUCTION

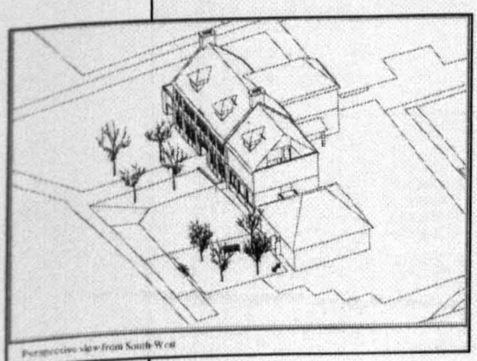
This learning task introduces the essential concepts and techniques for using AutoCAD AEC, (Release 4.0.), the Architectural, Engineering and Construction extension of the AutoCAD software system, to modify and extend an existing site and structure, shown in Fig.1 on page LT1-2, below.

The working session starts by entering AutoCAD AEC and making a working copy of the building model D:\CADIBS\ITS1_LT1.DWG. The remainder of the task demonstrates a sequence of fifty commonly used AEC procedures for constructing and manipulating components of the structure to achieve the modifications shown in Fig 2 on page LT1-3.

The columns labelled **Tasks** on pages LT1-4 to LT1-42 provide a short description of required modifications to the file. The columns labelled **Commentary** give guidance on the commands and functions necessary to carry achieve those modifications. Wherever possible the Commentary columns include references to online help available directly through the AutoCAD AEC system.

User requirements

Users of this learning task should be familiar with the follow concepts and techniques before starting:



1. Pull-down menus in Windows software.
2. The essential characteristics of model space and paper space in the AutoCAD system.
3. Using the ID command with object snap to identify points in an AutoCAD drawing.
4. Specifying absolute and relative coordinates in an AutoCAD drawing.
5. Use of Windows online help.

ITS_LT1A.CHP : CW : 15-NOV-94 **Page LT1-1** Copyright LCADC, De Montfort University

Fig. 40 Instructional method 3, Component 1 : Statement of objectives, content, methods and required existing capabilities

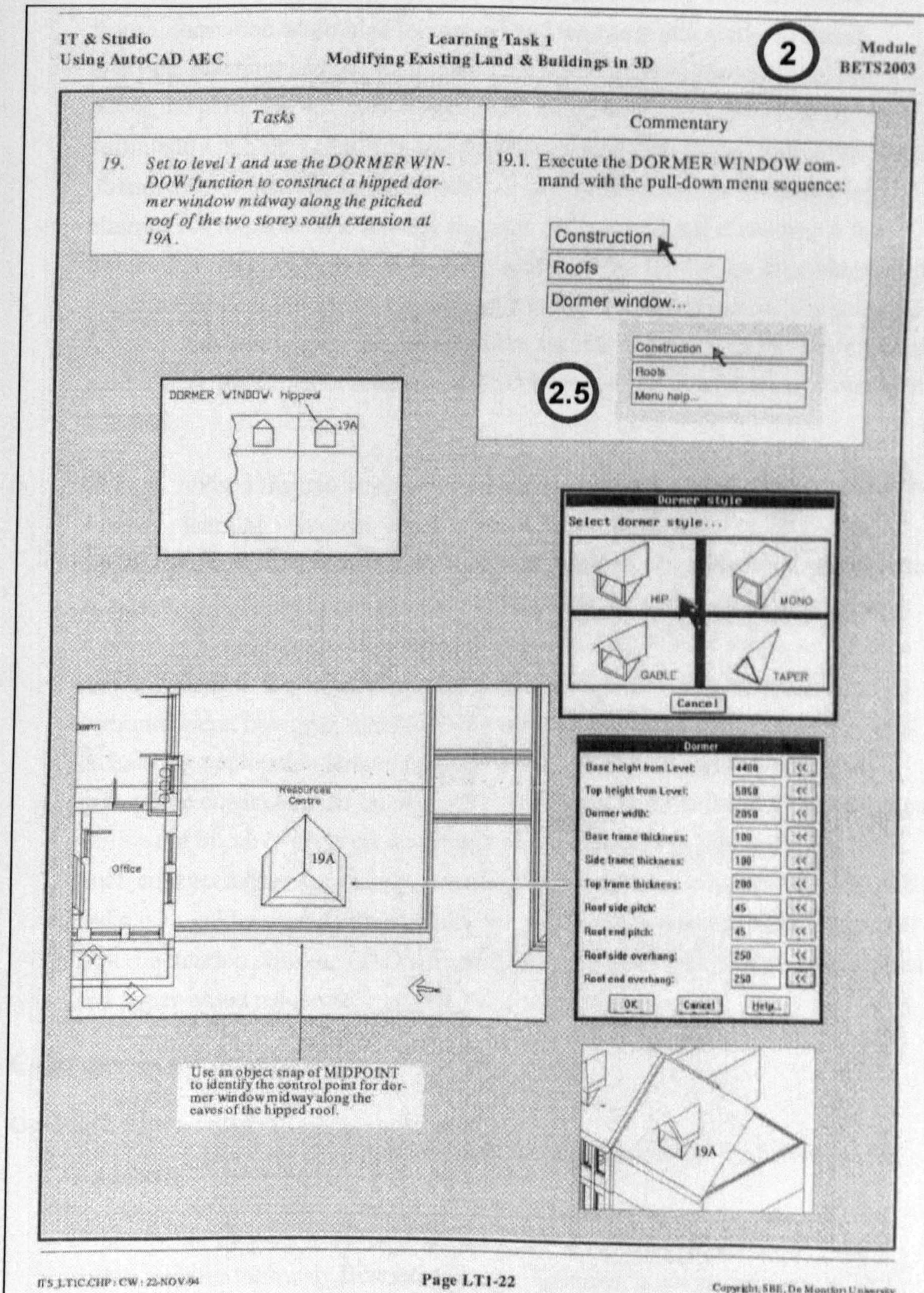


Fig. 41 Instructional method 3 : Component 2 : Revised paper-based method summary in a learning task.

Although it was logical to format the content for learning tasks automatically from information assembled by manual and interpersonal methods during analysis, planning and design in Steps 1-4 of the process (described in Fig. 34, p206) the particular methods investigated failed to improve productivity sufficiently in Step 4 to justify prerequisite manual operations. Moreover, results obtained from Instructional methods 1-3 indicated a need for investigating alternatives to paper as a delivery medium for instructional resources in the model. For these reasons techniques to automate the final stage in production of paper-based documentation consequently reduced in significance. The potential for, and constraints upon, automating core aspects of Stage 1 in the instructional model were investigated further in R & D Phases 4 and 5, as discussed on pages 293-381.

Overall, revised Instructional method 3 (pp217-221) delivered more compact and cohesive learning resources which trainees found quicker and easier to use, whilst experiencing less of the tedium from step-by-step guidance than had been apparent with Instructional method 1 (p168-169). Of the methods developed in the research programme it remained the preferred alternative for paper-based learning tasks in the concluding model (Fig. 108, p417). The format and modus operandi were, however, inherently more suited to guided discovery learning of an existing application strategy for CAD. Further R & D was indicated to investigate enhancements for developing knowledge, understanding and practical abilities to improve upon existing application strategies and identify new ones. Such enhancements were likely to require supplementing of paper-based learning tasks with guidance and opportunities for self-directed learning through parallel experimentation with the CAD software, browsing and selection of other on line and paper-based resources.

Computer-based resources

On-line Expert-Tutor

Rationale

Experiments with Instructional Method 3, discussed on pages 210-221, had shown trainees variously frustrated in their attempts to use proprietary on line help systems. Effective learning was constrained initially by the need to express requirements in unfamiliar terms when seeking guidance on software concepts, techniques and applications. Difficulties were compounded by the subsequent requirement for recognising content relevant to a knowledge deficiency whilst browsing extensive technical information. The potential anticipated by Ayerst (1987, p68) and others for using knowledge engineering techniques in computer-based instruction suggested a potential means for remedying such deficiencies:

> "Probably the most significant change in authoring [for computer-based learning] that will take place over the next few years is the incorporation of Expert Systems. An Expert System is able to emulate expert thought to solve problems. That is, it is able carry out some of the advisory functions of the tutor in training by recommending further work, remedial action, understanding answers that are not in standard format, and understanding why answers are wrong, etc."

Experiments with such technology in R & D Phase 3 investigated opportunities for achieving a more responsive interface onto computer-based instructional material prepared collaboratively by the instructional designer, instructor and CAD system expert as an alternative to proprietary resources for on line help.

Components and methods

An initial experiment with guiding trainees in selection and execution of commands in a CAD system involved linking knowledge engineering software (XpertRule) with multimedia sequences (Authorware) as summarised in Fig. 42, p223.

Requesting assistance from the CAD system menu (Fig. 43①, p224) started a consultation in which the prototype software attempted to clarify the trainee's problem through rule-based dialogue (Fig. 43②). The system then recommended a solution (Fig. 44, p226) based upon attribute settings (Fig. 43a②) and scanning of a decision tree shown in Fig. 43a②. Multimedia sequences were included to clarify key concepts and techniques as necessary during the consultation (Fig. 43③). Additional descriptions of methods, software tools and techniques used to construct the prototype are included in pages 48-53 of Section 2, and Appendix 4.

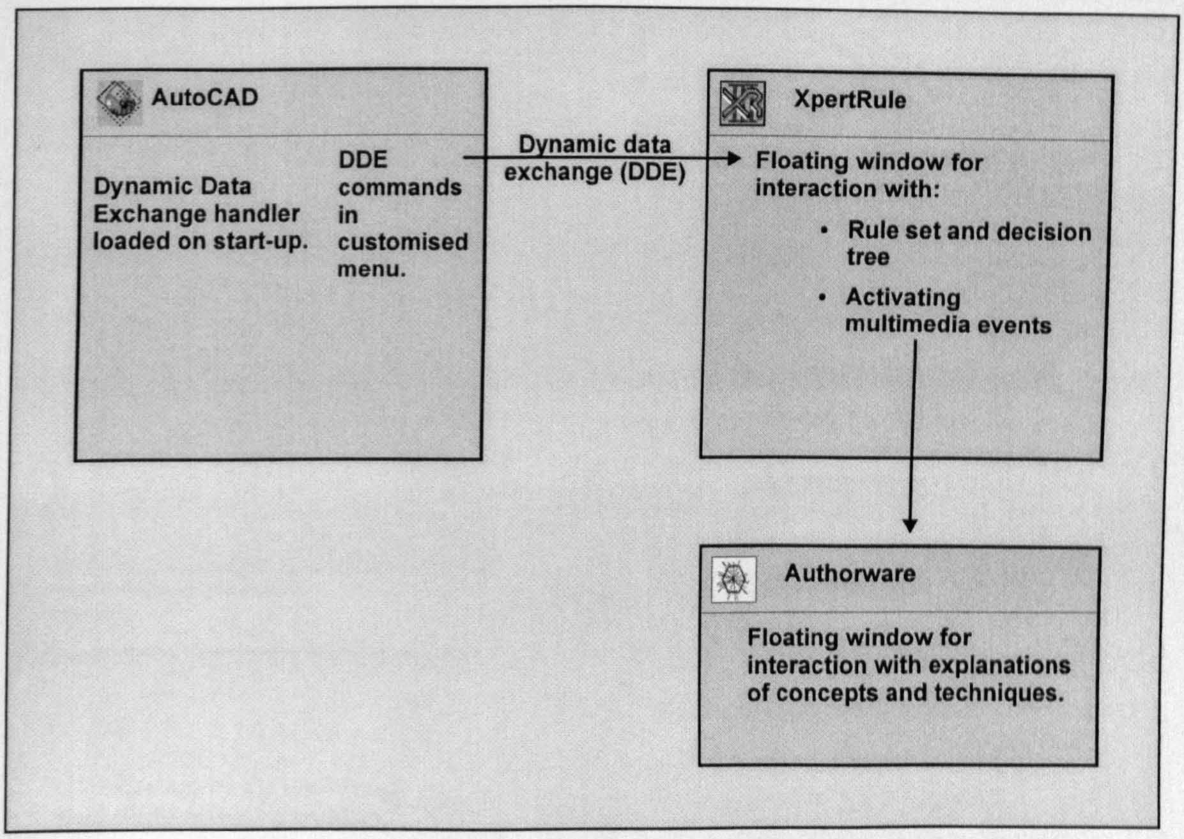


Fig. 42 Structure of the On-line Expert-Tutor

Limitations of the knowledge-based system (KBS)

Unfortunately initial testing of the prototype On-line Expert-Tutor demonstrated substantial limitations of the knowledge engineering software available to the author for guiding trainees through selection and execution of commands in a CAD system. One major constraint was the presumption in the system for mutually exclusive attribute values as the basis for deciding what advice to give the trainee. Although the software provided some flexibility through a mechanism termed "fuzzy logic" it was not conducive to an iterative process in which a trainee might rapidly modify his or her use of the CAD software and consequent questions of the knowledge base in response to results achieved from either system.

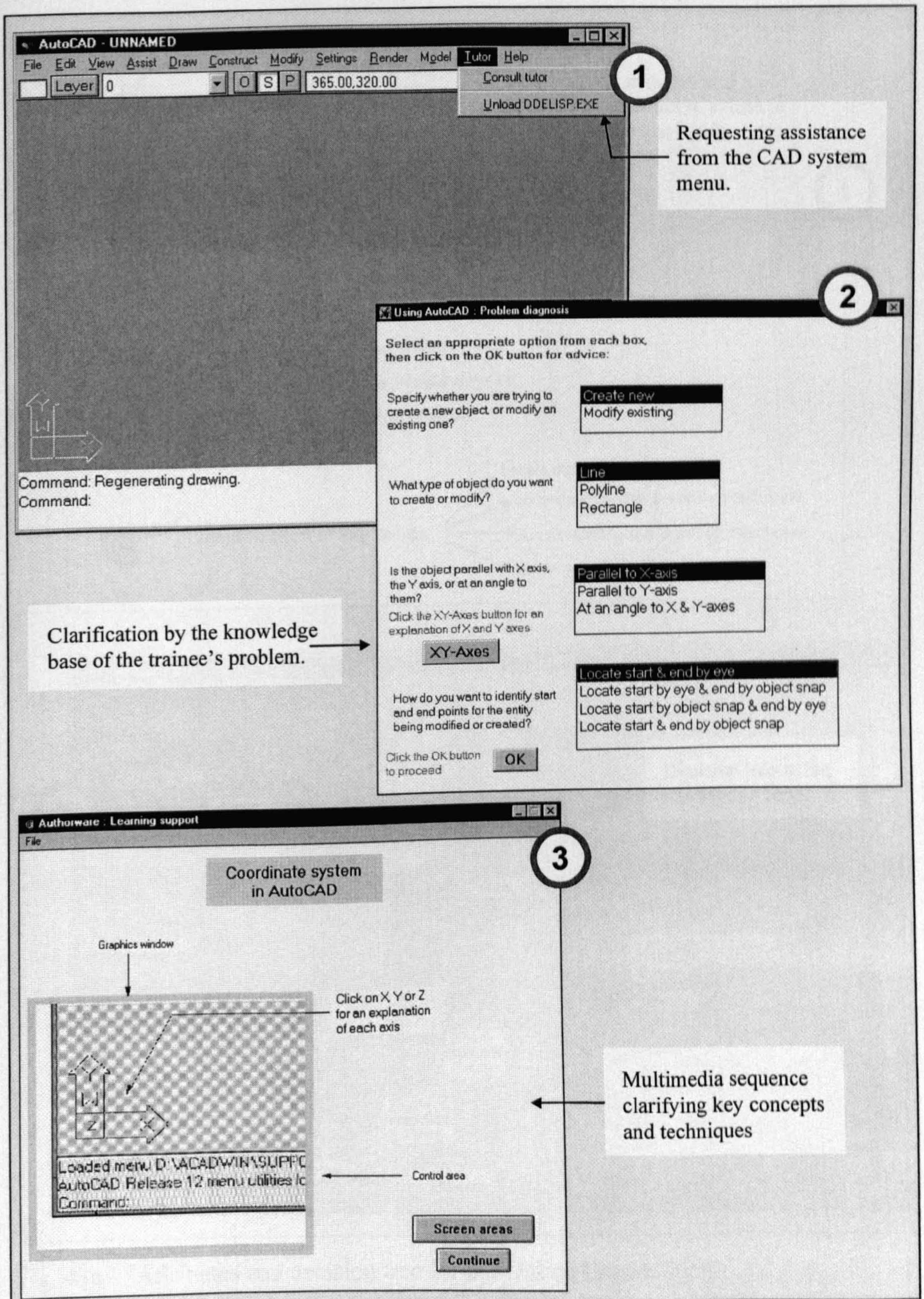


Fig. 43 Prototype for the On-line Expert-Tutor to guide trainees in selection and execution of commands in AutoCAD

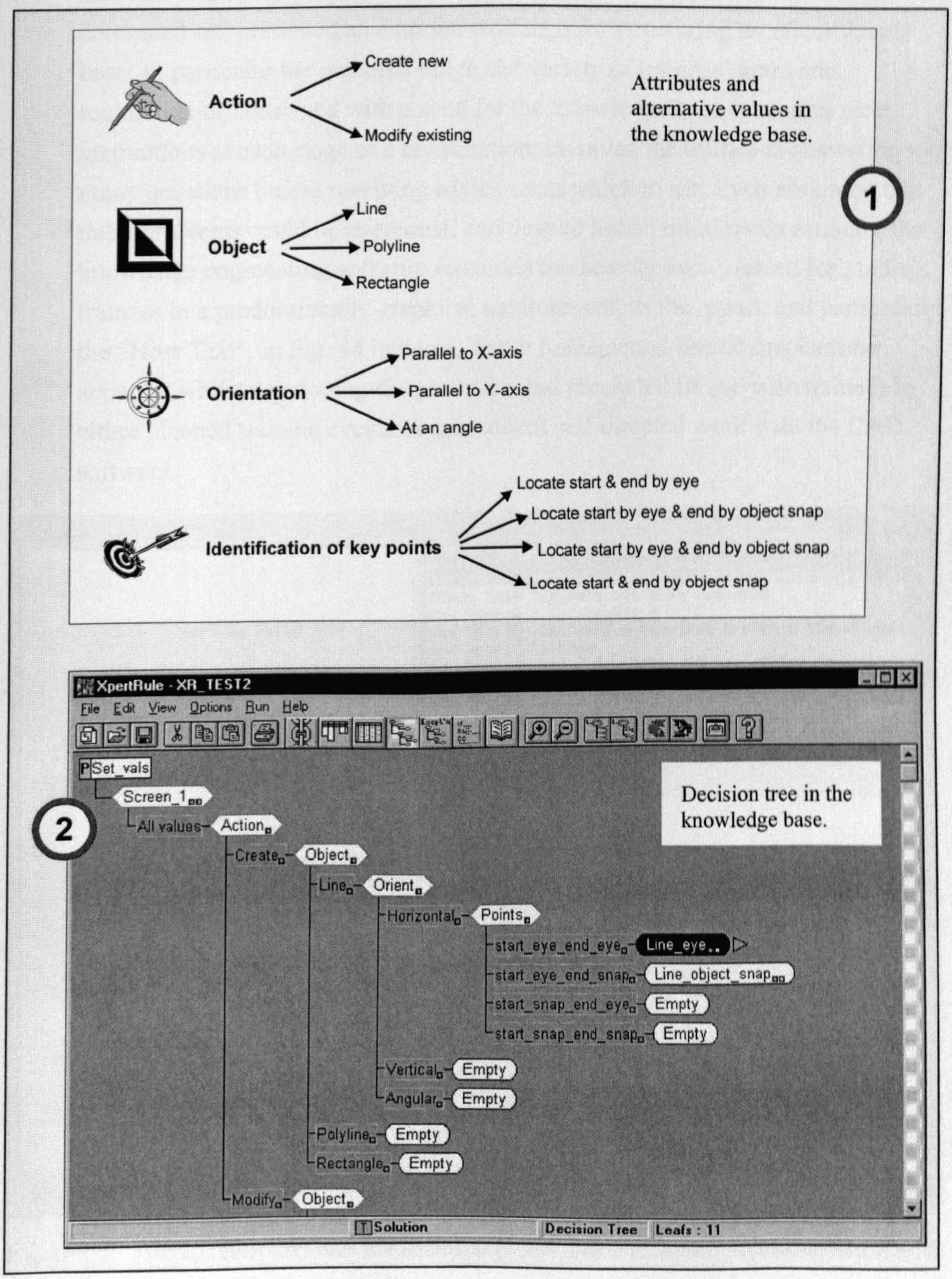


Fig. 43a Attributes and decision tree for the Online Expert Tutor

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The size and complexity of the CAD system (AutoCAD), its interface and command set, presented an extreme challenge for structuring an effective rule base. In particular the potential range and variety of trainees' authentic requirements, combined with a need for the knowledge base to receive clear instructions at each stage of a consultation, involved the trainee in answering too many questions before receiving advice upon which to act. Even assuming that these problems could be overcome, and despite linked multimedia routines, the knowledge engineering software remained too heavily text oriented for guiding trainees in a predominantly graphical environment, as the report, and particularly the "How Text", in Fig. 44 indicate. These fundamental limitations became apparent whilst developing the prototype and precluded its use with trainees in either planned training events or subsequent self-directed work with the CAD software.

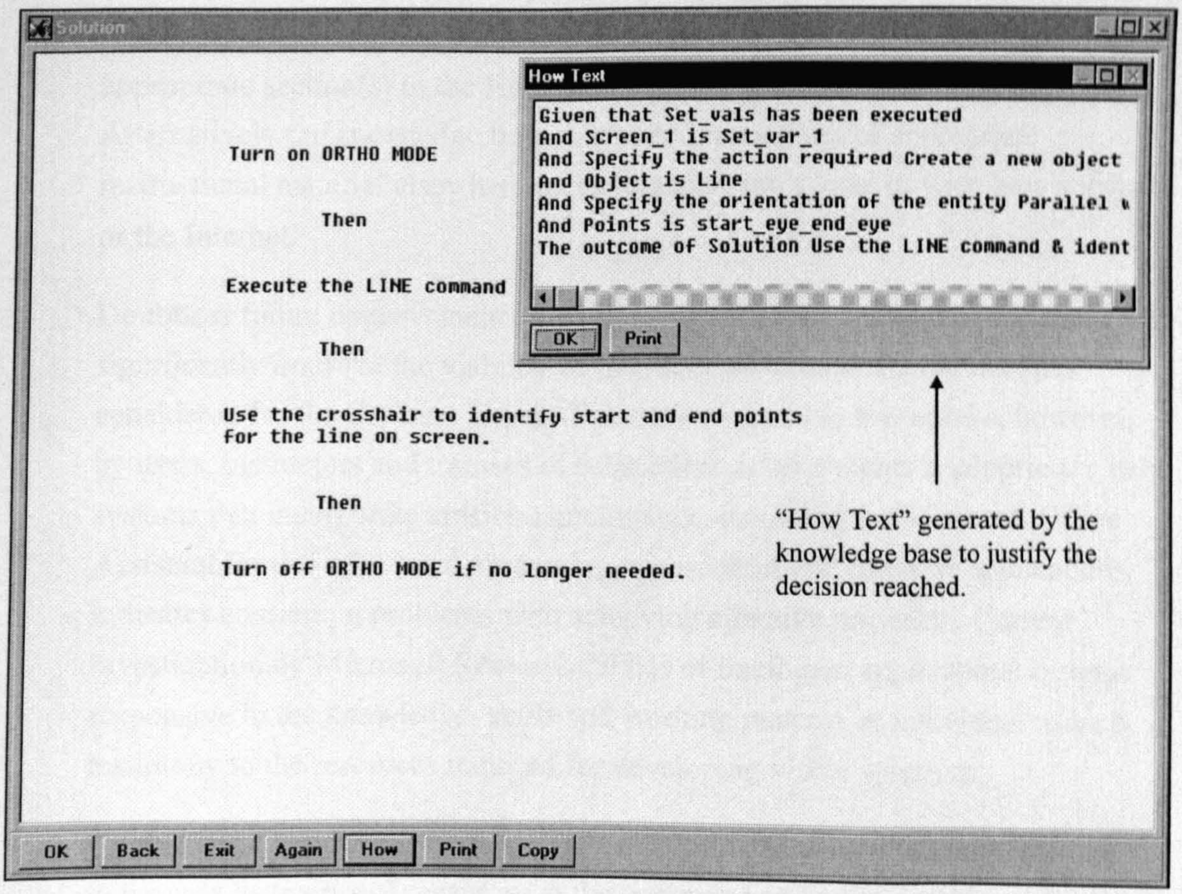

Fig. 44. Advice (Report) and justification (How Text) following a consultation with the On-line Expert-Tutor.

Results from prototyping a knowledge-based guide to CAD procedures indicated that developing adequate provision with the software tools available was not viable. However, XpertRule and comparable proprietary knowledge engineering systems are able to generate source code for inclusion in other software applications. Although possibilities existed via this route for overcoming some of the difficulties described above with interfacing, they were beyond the resources and technical scope of the research programme to investigate further. A subsequent decision to use Multimedia ToolBook software from Asymetrix Corporation rather then C++ for prototyping instructional resources, made for reasons discussed on pages 50-52, precluded the option to embed such code.

A potentially productive response to the high costs anticipated in achieving the customised guidance envisaged might involve a hybrid solution. In this scenario a knowledge-based system would be used to diagnose a trainee's requirements more effectively than a proprietary Help interface, but then transfer him or her to appropriate section(s) in the Help files supplied with the CAD software. Alternatively the knowledge base might recommend use of appropriate instructional material elsewhere on the organisation's local or wide area network or the Internet.

Doubtless future improvements in artificial intelligence techniques and tools will significantly improve the viability of instructional components of the kind considered for the On-Line Expert-Tutor. An observably low uptake, however, by users, instructors and trainees of subsequent developments in proprietary help systems that incorporate artificial intelligence, including the Microsoft Office Assistant for use with word processing, spreadsheet and database applications, indicates continuing problems with achieving effective provision. Current investigation by Microsoft Research (2001) of intelligent applications systems responsive to the knowledge, skills and working patterns of individual users is testimony to the resources required for developing viable solutions.

Although the underlying rationale for using knowledge engineering technology to provide instructional resources at the command and procedural level for CAD remained fundamentally unfaulted by experiments, further practical work to develop corresponding software could not be undertaken. Experiments with the On-line Expert-Tutor did, however, demonstrate potential utility in two other important respects. In the first instance they demonstrated the feasibility of integrating output from other applications software with the core CAD system to prototype computer-based components prescribed in the developing instructional model. Secondly, they suggested opportunities to use rule-based decision making mechanisms for more strategic purposes elsewhere in the training process. These possibilities were explored further in R & D Phases 4 and 5 as discussed on pages 293-381.

Mental Modeller

Rationale

Proposals for an instructional resource termed the Mental Modeller originated from a need observed in planned CAD training by conventional methods for instructors to scan the experience of trainees in search of relevant analogies through which to explain required concepts and techniques. The work of Sein, Olfman and Bostrom (1987, p242) subsequently provided a more structured rationale for mental modelling in training end users to use computer systems:

> "The crucial objective in training is to provide the trainee with the know how and desire to use EUC [end-user computing] on the job. ... Mental models are mental or internal conceptual representations of the software the user is learning. ...To be effective, a training programme should provide aids that will help users form initial mental models."

The Mental Modeller was conceived in this context as a computer-based tool for explaining operational requirements of the CAD system using analogies familiar to the individual trainee in clarification of associated concepts and techniques. The instructional software was intended to range between passive and active in use. This requirement accorded with advice from Scandura (1983) and Merrill (1983) that instructional methods should accommodate variations in the learning traits of trainees, and changes in their capabilities and preferences as they occurred in response to instruction. The concept was further informed by discussion and recommendations in Dryden and Vos (1994) of the role of mind maps in problem solving.

Components and methods

Software components for the prototype Mental Modeller are shown in Fig. 45 (p229). A DDE instruction in a customised AutoCAD menu activated a

ToolBook[1] floating window to support dialogue with the trainee and coordinate the instructional sequence through OpenScript routines.

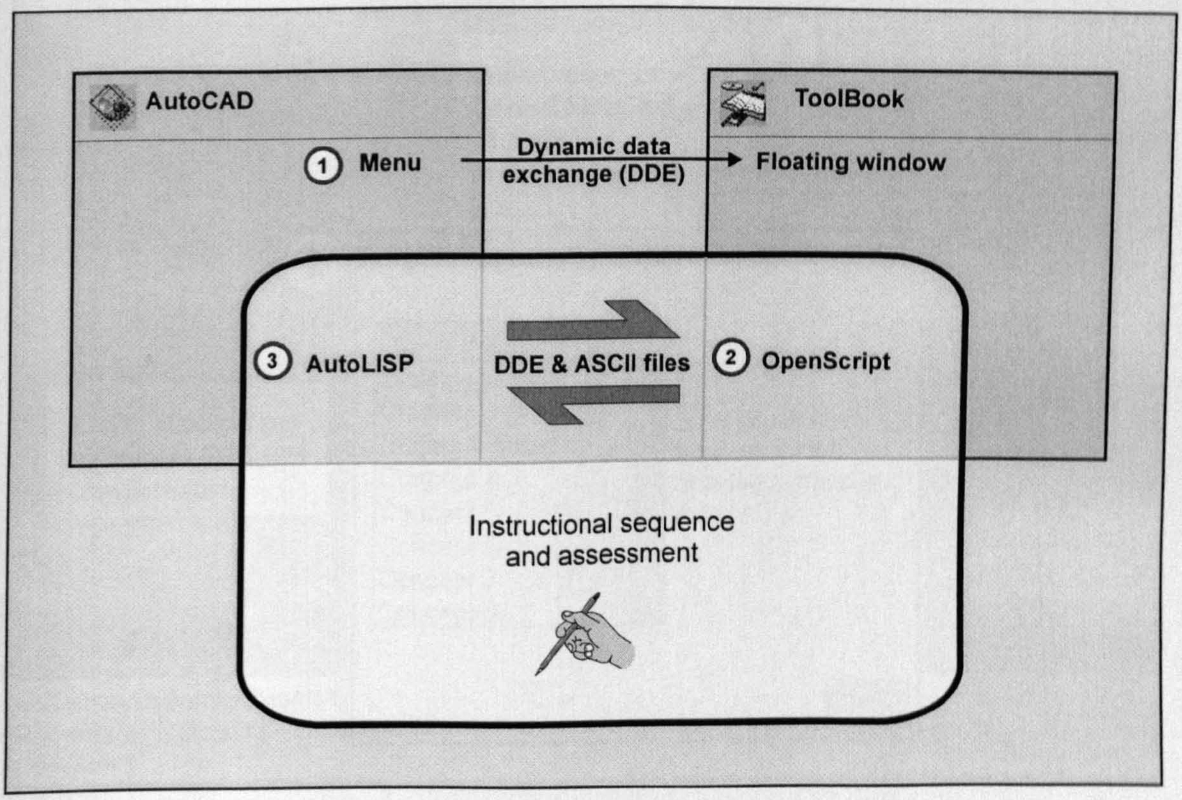

Fig. 45 Software components in the prototype Mental Modeller

Instructions issued by ToolBook through other DDE code in response to actions from the trainee activated LISP routines in AutoCAD to control display of explanatory text and graphics in the main graphics window of the CAD system. The trainee's interaction with the CAD software was then monitored by more LISP procedures which returned results in ASCII files to ToolBook for interpretation, and subsequent delivery of appropriate advice to the trainee.

Events typical took place in the following sequence. Selecting the menu option for Mental Models in AutoCAD (Fig. 46①, p230) displayed a list of concepts and techniques expressed in language relating primarily to 2D drafting rather than technicalities of the CAD software system (Fig. 46②).

1 The ToolBook authoring system was concurrently in use by Autodesk (1996) to produce Inside Track, the company's computer-based training package.

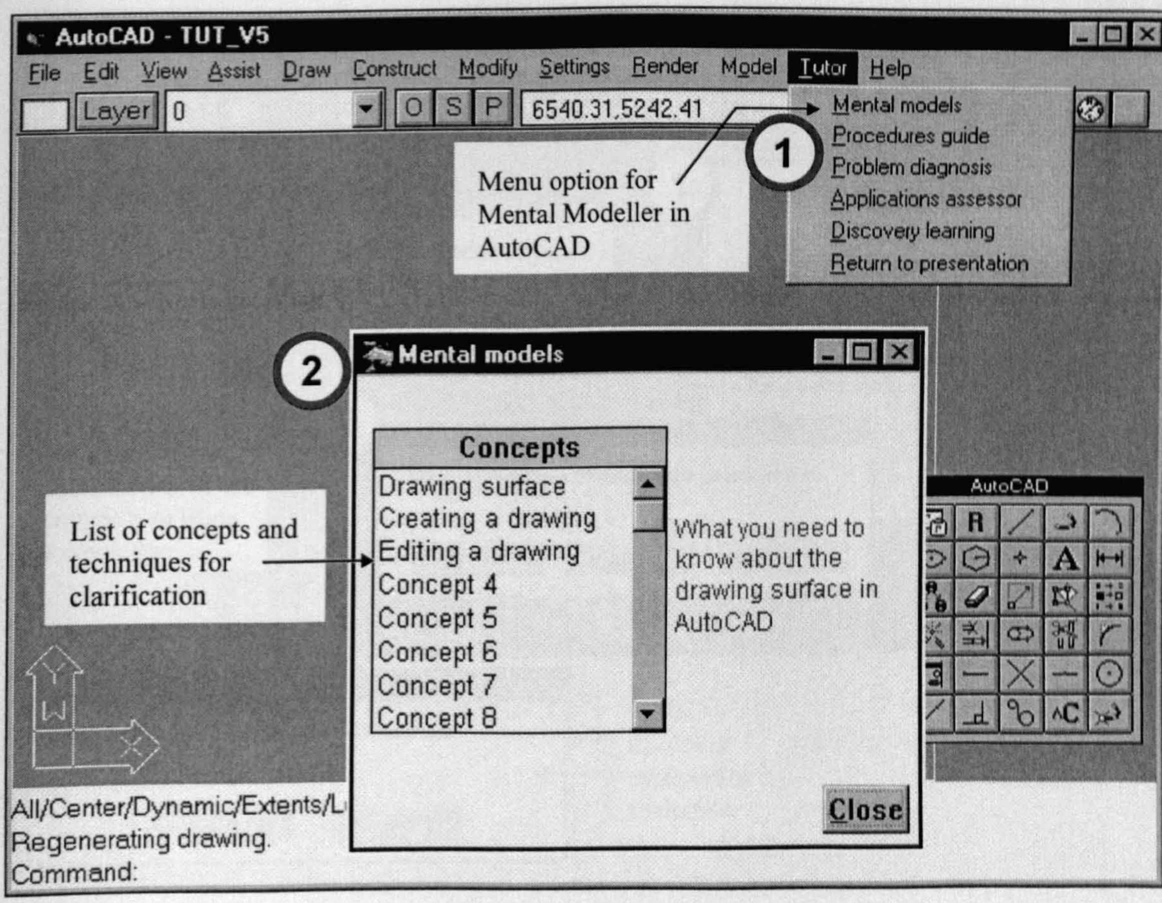

Fig. 46 Accessing the Mental Modeller from AutoCAD

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In response to the trainee's selection from the list the software displayed general guidance on the specified subject (Fig. 47①, p231) before requesting clarification of the trainee's existing knowledge (Fig. 47②). Depending on the trainee's answer a choice of explanation analogies was offered as shown in Fig. 47③. The instructional sequence which followed used text, sound, and images to explain the chosen concept through the preferred analogy, and required the trainee to interact at his or her own pace with the Mental Modeller prototype and the host CAD system (Fig. 48①, p232)[1].

1 Watts (1996, p176)

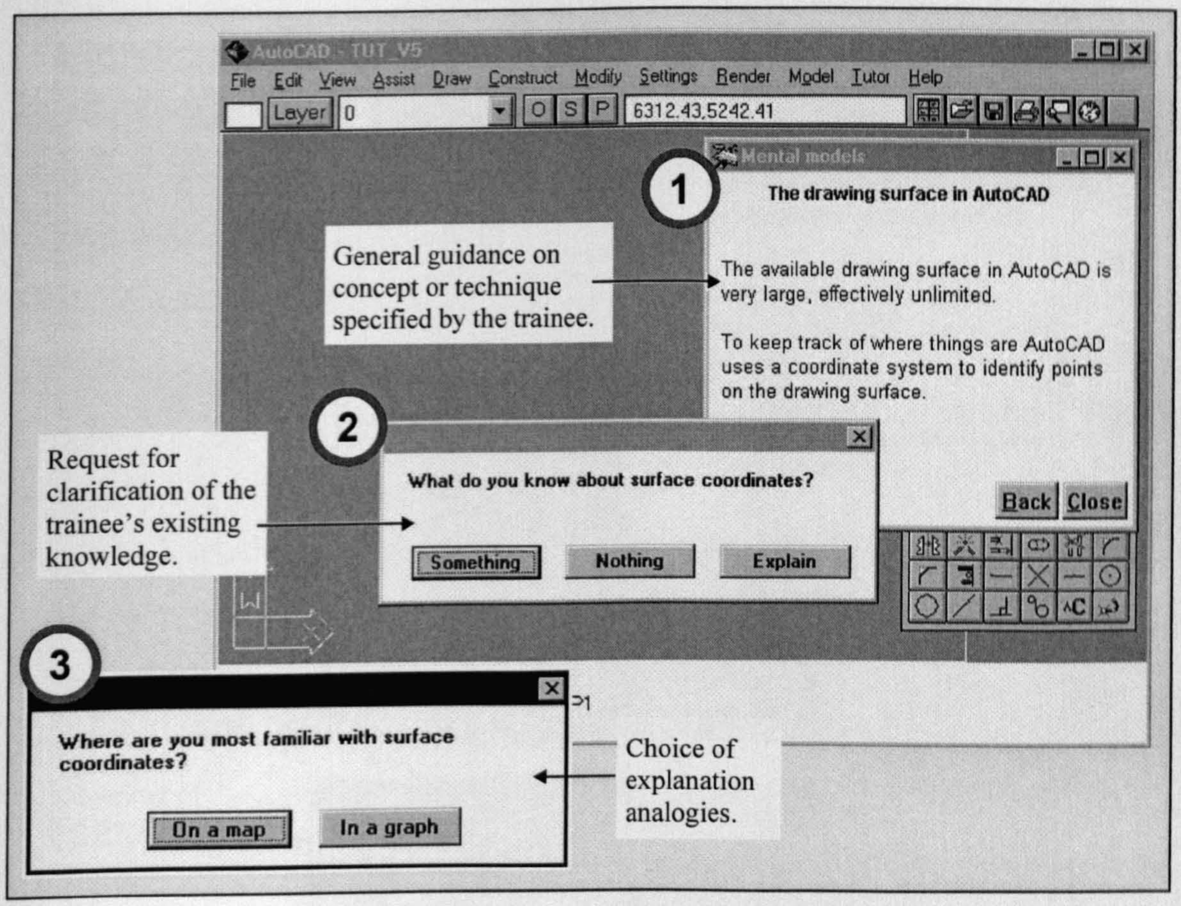

Fig. 47 Identifying a relevant analogy in the Mental Modeller

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At the end of the instructional sequence the trainee's understanding of relevant concept(s) and technique(s) was tested by answering questions posed by the Mental Modeller and by performing actions within the CAD system (Fig. 48 (cont'd.)②, p233). At the end of the test the instructional software responded with appropriate remedial advice on the trainee's performance (Fig. 48 (cont'd.)③).

Results from prototyping the Mental Modeller

Although construction and use of the prototype was hampered by inadequate documentation of DDE for the software systems involved, (discussed on pages 52-53), experiments with the Mental Modeller demonstrated potential utility of such a mechanism for instruction and learning of CAD concepts and techniques through analogies individualised for the trainee.

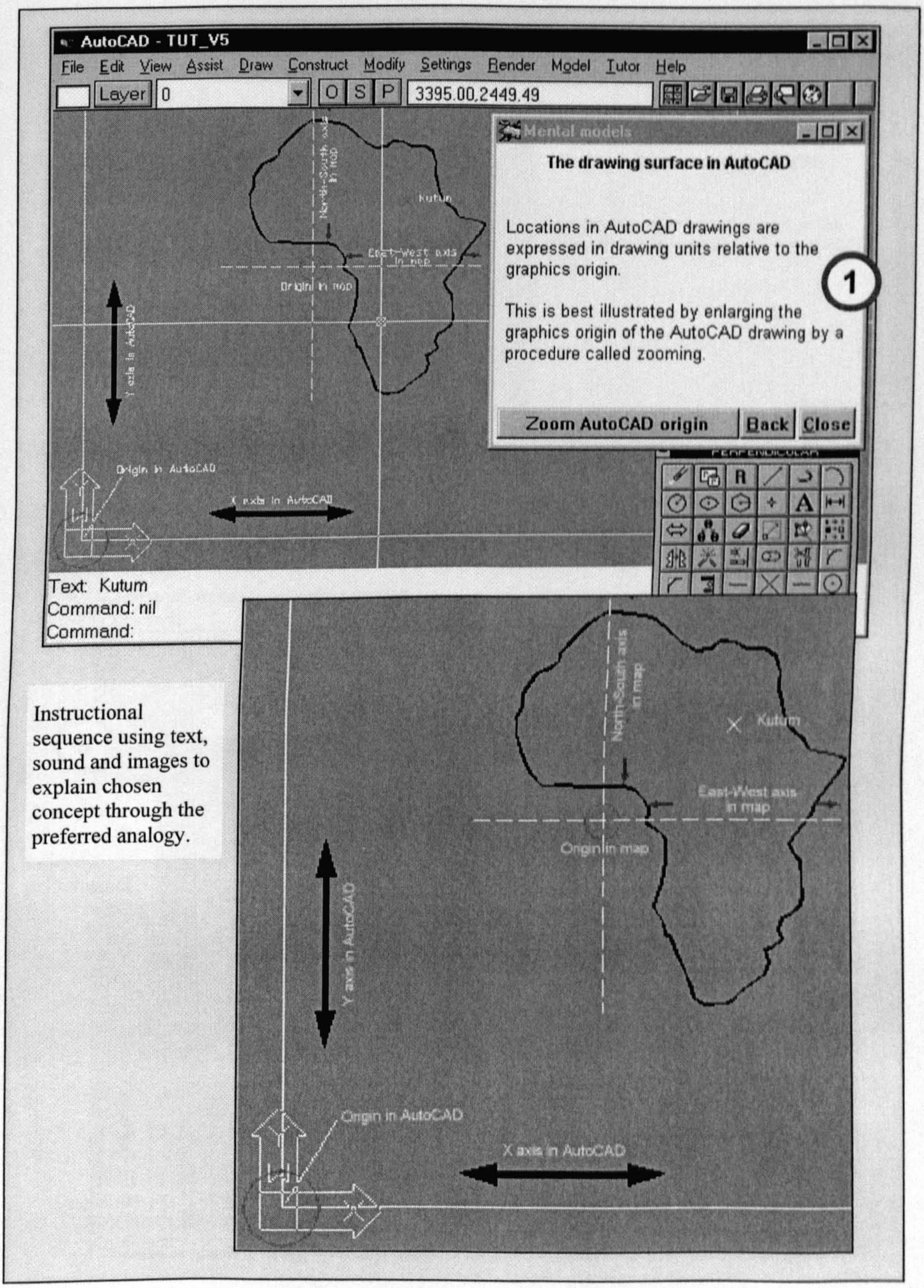

Fig. 48 Interactive sequence in the Mental Modeller and AutoCAD

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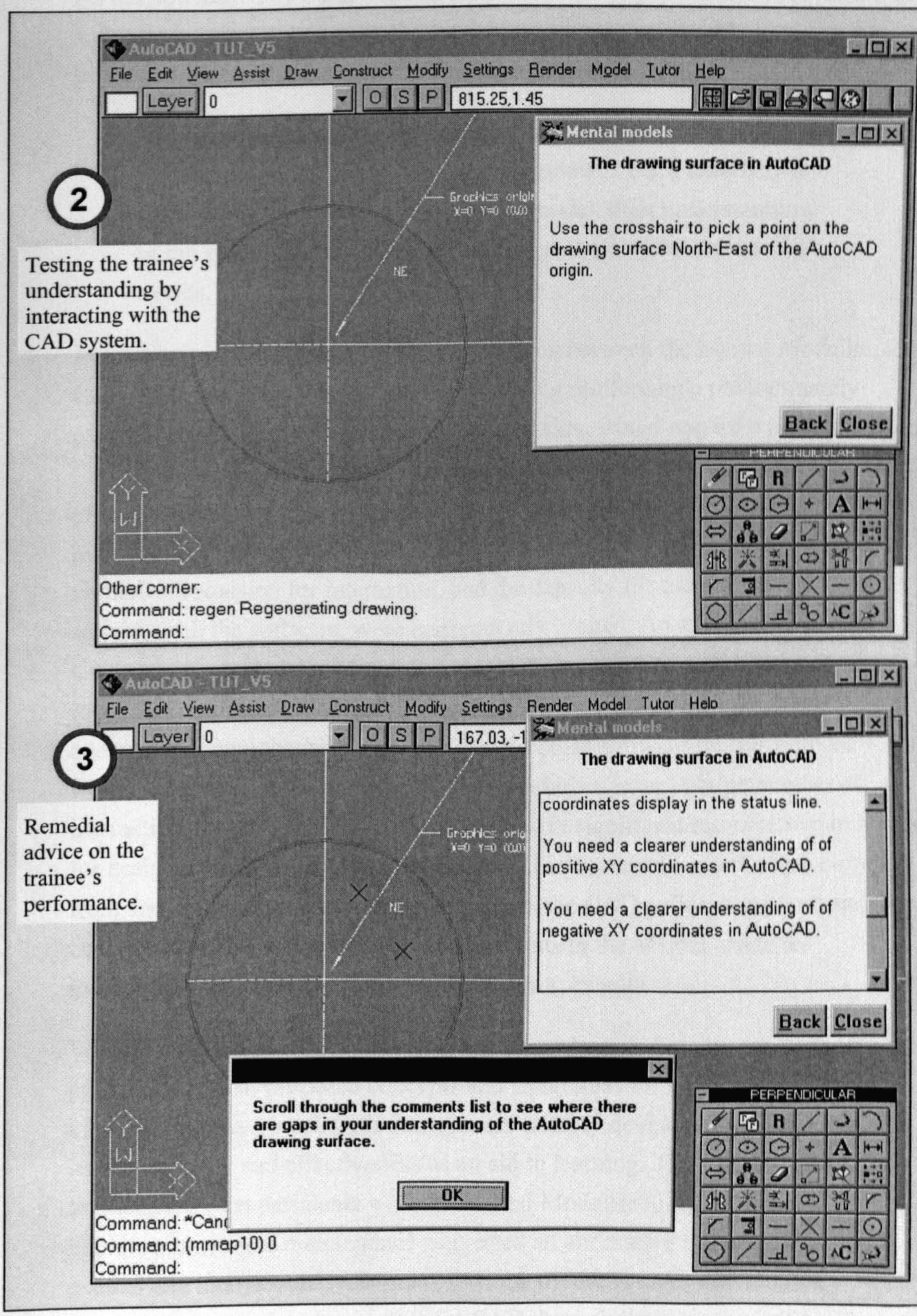

Fig. 48 (cont'd.) Interactive sequence in the Mental Modeller and AutoCAD

Source: c:\icad_rep\report1.tbk; c:\acadwin\support\mmap1.lsp

As acknowledged by Sein, Olfman and Boston (1987, pp242-3) for applications software in general, however, the level of interaction achievable between the trainee and CAD system remained a critical issue:

> "Novice users need to experiment with the system to form and test hypotheses about using their mental models ... Each time they test the boundary condition of the mental model, their understanding of the system is extended, and a richer and more accurate model results."

Achieving a corresponding level of interaction between the Mental Modeller, the CAD system and trainee, and thereby avoiding reinforcing a predominantly passive learner's reliance upon external direction, would require a programmable CAD system with suitable opportunities for controlling the interface. In the case of the mechanism prototyped, only limited integration was possible between the instructional system, the AutoCAD environment, its internal data and system variables. Provision for interaction, and the capacity for monitoring the trainee's activity with the software, were consequently limited. An application written in C++ and conventionally bound to AutoCAD was required to achieve a more robust and capable learning resource. Furthermore, achieving and maintaining adequately comprehensive and sufficiently robust software for this purpose would incur substantial and potentially prohibitive costs. A large number of interactive events would be required, each with significant resource requirements for design, production and implementation. Unfortunately, much of the output from such effort would need modification as the CAD software evolved and changes in successive releases rendered events in the Mental Modeller incomplete, inaccurate, or irrelevant to varying extents.

Whilst it was possible from the prototype, therefore, to broadly assess the potential utility of proposed concepts and techniques for an instructional tool, more testing was needed with trainees and suitably developed software to assess its acceptability and effectiveness as an aid to learning. The substantial resource implications of experiments with the Mental Modeller for development, implementation and maintenance suggested an alternative investigation of manual and interpersonal methods by which trainees could individualise proprietary instructional resources for CAD through their own cognitive processes. Indeed, provision for developing active learning, discussed on pages 249-273 subsequently emerged as a more viable means of enabling trainees to achieve appropriate mental models of CAD concepts and techniques than attempting to develop instructional software for the same purpose.

Procedures Guide

Rationale

Experiments with Instructional methods 1-3 had substantially endorsed for training in CAD the general recommendation of Landa (1983, p194) to achieve command of overall procedures through step-by-step instruction. As discussed on page 208, however, significant limitations remained with use of paper-based instructional sequences for this purpose. Indeed, Defects 2.3 and 2.5-2.8 identified for conventional training for CAD and summarised in Table 17, p143, could all be traced to varying extents back to the inherent limitations of paper-based instructional resources. Consideration of a computer-based Procedures Guide, discussed on pages 235-241, investigated the viability of an instructional designer supplementing proprietary provision by customising computer-based, step-by-step guidance for particular CAD procedures.

The On-line Expert-Tutor, considered on pages 221-228, had with limited success attempted use of rule-based knowledge engineering to overcome limitations of proprietary computer-based instructional resources for helping trainees navigate command sequences. By comparison the Procedures Guide anticipated multimedia equivalents of the procedural diagrams developed for Instructional method 1, (Fig. 16, p163). The mechanism would function to familiarise trainees with pre-specified procedures of particular relevance to building surveyors. This focus on specific application sequences distinguished the Procedures Guide from the computer-based Mental Modeller, discussed on pages 228-235, which had attempted clarification of CAD concepts and techniques by analogy. Similarly, inclusion of monitoring and diagnostic functions differentiated the Procedures Guide conceptually from "Cue cards" and "Show me" options in, for example, Microsoft Office applications. Since experiments with the Mental Modeller had suggested a danger of computer-based learning resources reinforcing a trainee's dependency upon external guidance the Procedures Guide would include both active and passive modes of operation.

Components and methods

A schematic of software components in the Procedures Guide prototype is shown in Fig. 49. The software was activated by instructions in a customised AutoCAD menu for displaying an interface created using the controls native to the CAD system. The trainee then selected an appropriate instructional topic and was guided through a corresponding activity sequence.

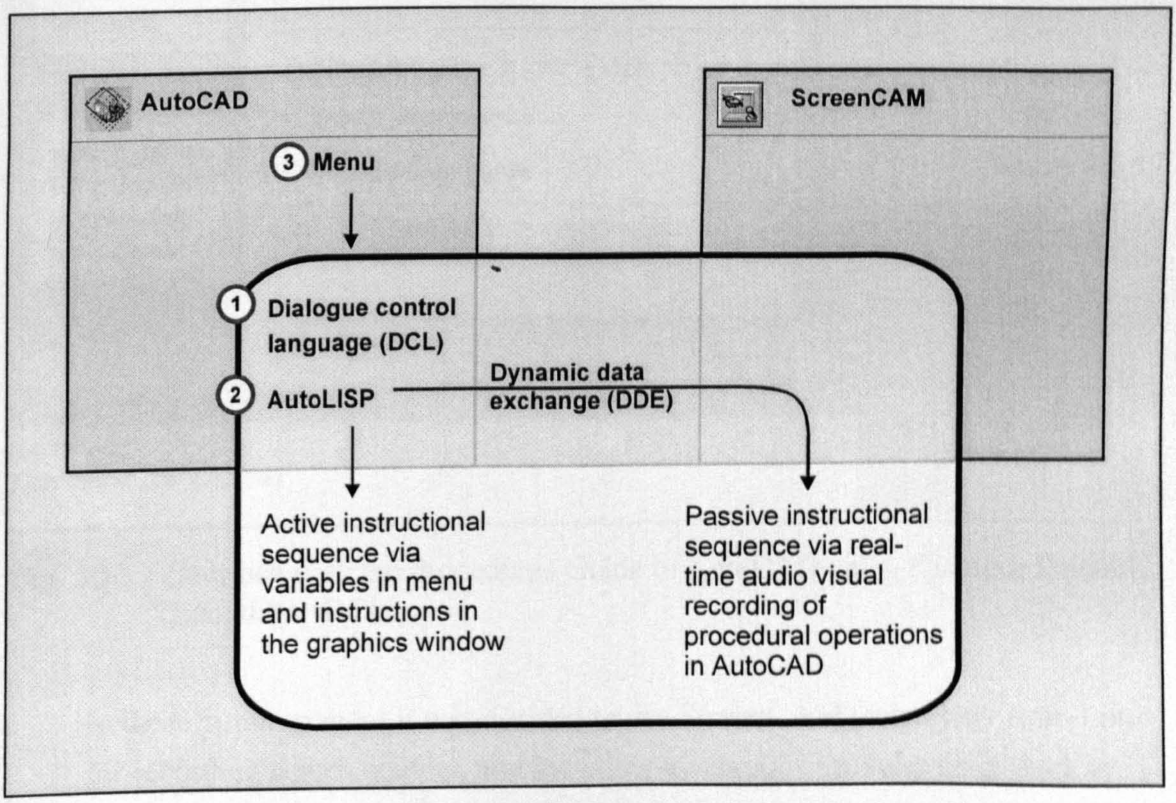

Fig. 49 Software components in the prototype Procedures Guide

The prototype for this component investigated use of Autodesk's native Dialogue Control Language (DCL) to create a user interface within AutoCAD as shown in Fig. 50 (p237). The intention was to reduce the need for adding software components to the CAD system, thereby alleviating the need for additional technical capabilities to design and produce learning resources. The passive option allowed a trainee to select from a menu of operational sequences and verbal commentary. For this option DDE instructions were sent to display corresponding real-time audiovisual recordings of relevant AutoCAD procedures. Attempts to video record instructional sequences directly encountered substantial problems was simultaneously including the computer screen, keyboard, mouse and operator (Fig. 9, p47).

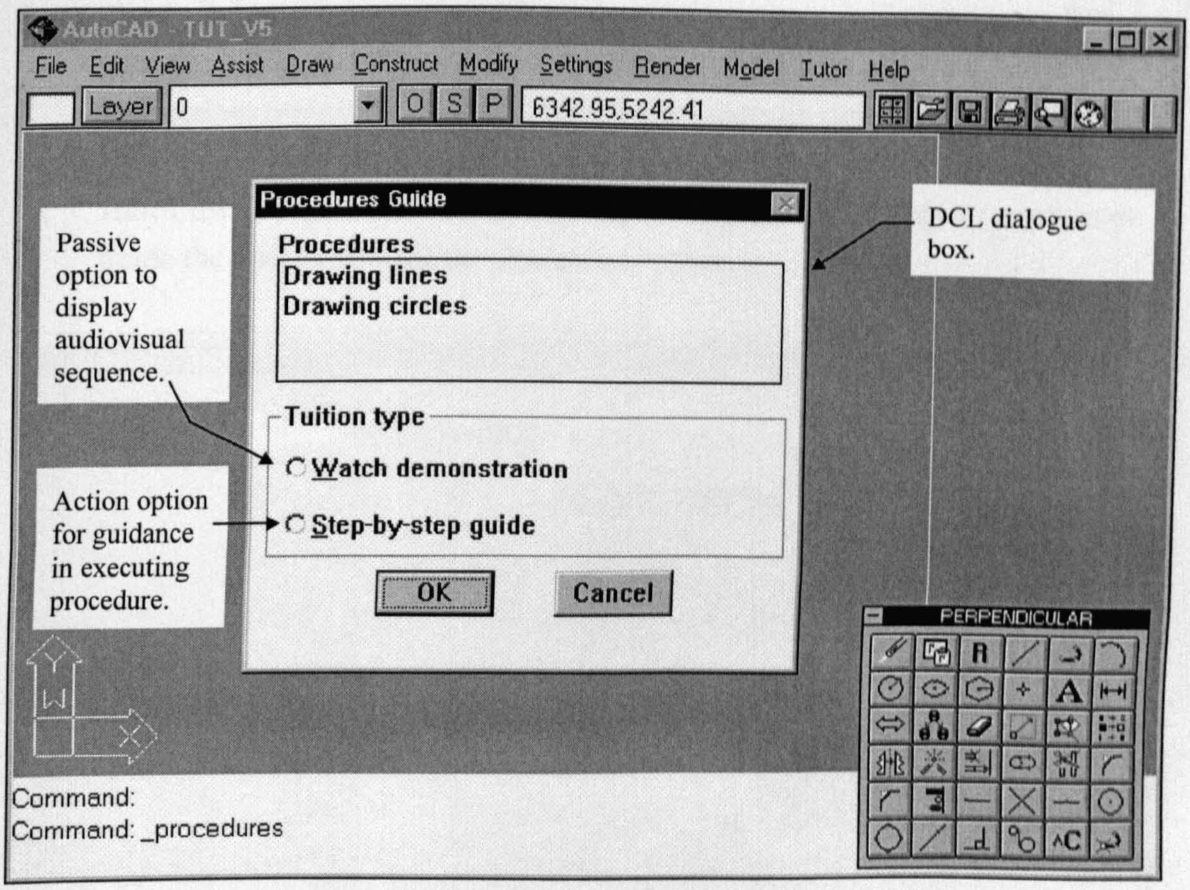

Fig. 50 Interface with the Procedures Guide in AutoCAD using Dialogue Control Language (DCL)

In these circumstances it was decided to use ScreenCAM technology from Lotus for recording screen activity, and including an appropriate voice-over track or popup text boxes in clarification of the visual sequences presented. A control widget displayed with each sequence allowed the trainee to pause, play or end the presentation as required (Fig. 51).

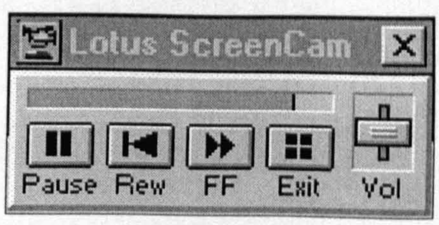

Fig. 51 Controls for replaying CAD application sequences.

The active option used AutoLISP, customised AutoCAD menus and display of instructions in the graphics window to prompt the trainee through the required procedure whilst monitoring his or her interaction with the CAD system as shown in Fig. 52. Correct responses cued the next step in the sequence. Where a procedure was executed through cascading menus then embedded AutoLISP instructions assigned variables to present appropriate cues in the pull-down lists. Where menu sequences ended before completion of the procedure then the AutoLISP code inserted blocks in the graphics window displaying prompts to guide the trainee through the remaining sequence.

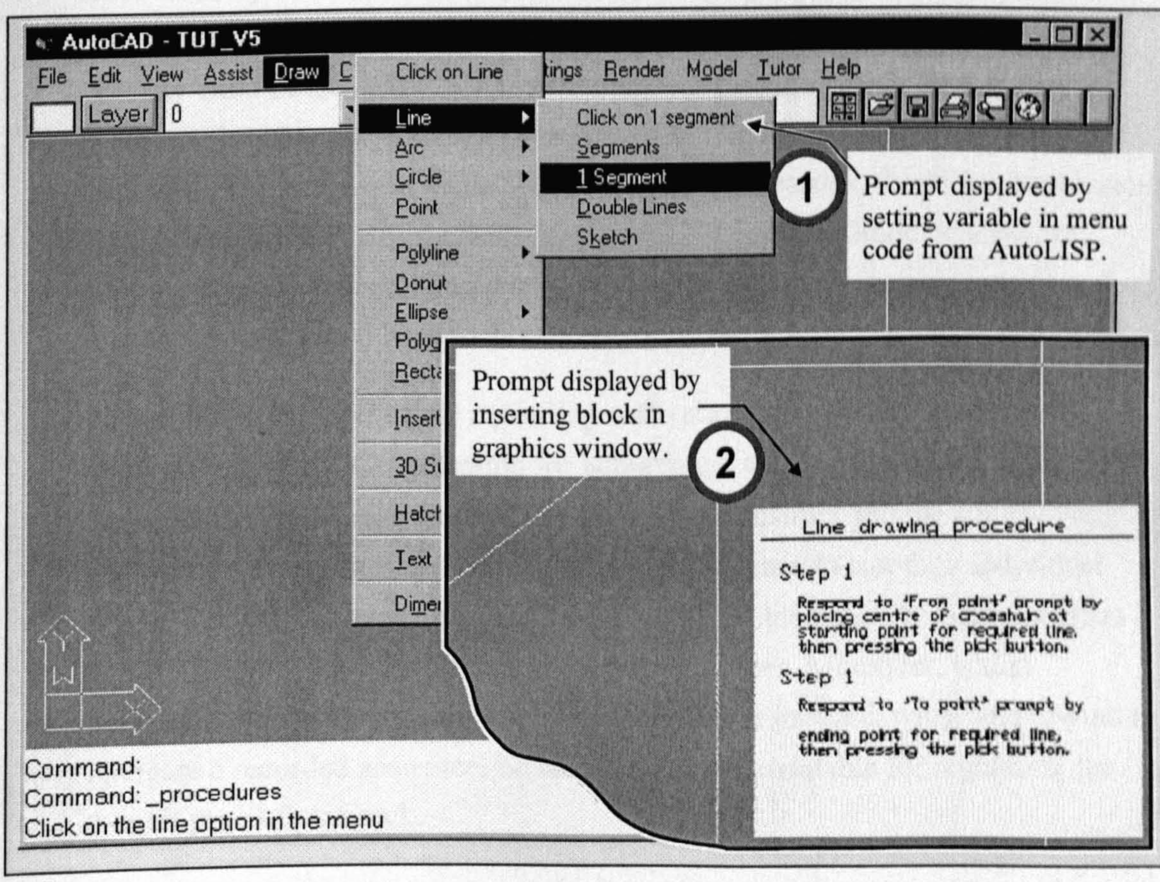

Fig. 52 Procedures guide in AutoCAD using a menu customised with AutoLISP, and inserted blocks

(Source: c:\acadwin\support\tutor1.lsp; c:\et_su\et_su5c.mnu; c:\acadwin\support\et_su5c.mnl

Results from prototyping the Procedures Guide

In terms of essential operability of the Procedures Guide significant problems were encountered interfacing the prototype software to the host CAD system. Although constructing an interface with AutoCAD's dialogue control language (DCL) removed the need for an add-on component and reduced complexity of the instructional software it proved less flexible than the ToolBook viewers and OpenScript routines described for the Mental Modeller on pages 228-235. No satisfactory mechanism was found in AutoCAD for providing robust, unintrusive cues on the screen once display of pull-down menus had finished in a command sequence. Command line prompts, alert boxes, insertion and automatic deletion of blocks all proved too fragile for use in the learning tool where, of necessity, the user interface must withstand inadvertent misuse. As with other prototypes, this difficulty indicated the need for a C++ or similar application bound to the core CAD system. Alternatively, technical developments in subsequent versions of the CAD software might provide scope for solutions. Such potential may already exist in the AutoCAD Internet utilities through which objects in a trainee's drawing file could be hyperlinked to relevant guidance in HTML documents on the World Wide Web. For technical reasons, therefore, conclusions drawn here on the viability and utility of the Procedures Guide concept are necessarily tentative pending testing with more robust mechanisms, as described earlier for the Mental Modeller.

Use of proprietary real-time recording software for the passive mechanism showed some potential in testing for achieving a viable instructional tool. ScreenCAM recordings were relatively easy to construct and the control widget allowed trainees to navigate an instructional sequence to suit their individual needs. These benefits were offset, however, by problematically large data files and limited provision for editing recorded sequences. Moreover, whilst ScreenCAM provided for the basic controls of fast forward, pause and rewind to navigate a recorded sequence, no mechanism was available for regulating the overall pace of playback.

Testing with first year undergraduates[1] showed a strong tendency for trainees to use the most accessible source of solution to their immediate difficulties in a learning task. Trainees usually sought guidance directly from instructors or colleagues before turning to media-based instructional resources, whatever format they might take. This propensity was largely unaffected by variations in the potential of different methods for developing their learning capabilities. Students consequently used recorded sequences in the Procedures Guide only when recourse to interpersonal methods was constrained. Some of the observed

1 De Montfort University Module CNST1005 : Spatial Information Systems, an introduction to essential concepts and techniques of information and communication technology.

reluctance to use the prototype could be attributed, however, to expedient substitution of popup text descriptions for voice-over commentary to overcome difficulties with audio controls on the available computers. Students tended to find the resulting instructional sequences slow in use because of the pauses included for assimilating written content.

Subsequent experimental use of proprietary recorded sequences with voice-over commentaries from Autodesk's Learning Assistance for AutoCAD Release 14 with second year Building Surveying students[1] indicated other problems with the method. Whether to minimise file sizes, or in response to limited tolerances amongst users of extended sequences, the Autodesk recordings were delivered at a pace that many students found unhelpfully fast and constrained assimilation of new procedures. Moreover, the strong American accent and brusque delivery of the commentary voice appeared to distract some users. Notwithstanding the limitations of verbatim recordings and verbal commentaries discussed above, suppliers have since widely distributed such sequences for instruction in proprietary software. In the case of Autodesk this includes Inside Track (1996) and Learning Assistance (1997) although uptake of these resources has been observably limited amongst the practices with which contact occurred following the 1995 survey.

In pedagogic terms ScreenCAM remained only a presentation mechanism and provided no integral means for monitoring the trainee's response to recorded audiovisual sequences. Moreover, although the prototype provided for active and passive use, no mechanism was designed or implemented for automatic transition between the two modes in response to beneficial changes in the trainee's performance. Achieving such provision by computer-based methods would instead require incorporation of ScreenCAM presentations within a software shell able to undertake monitoring and assessment functions. Alternatively their use would need monitoring and assessment by manual and interpersonal methods.

Despite the operational difficulties discussed above, prototyping the Procedures Guide served to question the simplistic initial distinction of the investigation

1 De Montfort undergraduate module CNST2004, Design and Construction Processes 3.

between passive and active learning methods. It became clear that successful active learning of a CAD system might at times include apparently passive observation and assimilation of demonstrations and descriptions. Merrill (1983, p329) clarified the potential range in a learner's response to instructional resources, and the implications for instructional design, by observing that he or she is not passive when interacting with instructional materials, but instead undertakes one or more in a range of responses. Moreover, the activity in which a learner engages in response to instructional materials may be inappropriate or sub-optimal. Merrill asserts that the learner can be taught to optimise learning from any given instructional material using a strategy appropriate for the type of material, and which compensates for inadequacies in its particular design and instructional capabilities:

> "This explicit direction of processing appropriate for a given display [learning resource] in the context of a given outcome class may be an interim step leading to learner control of appropriate learning strategies." (Merrill, 1983, p330).

The emerging case for a hybrid of computer-based, interpersonal and manual methods for instruction and learning, in which the instructor and trainee act to optimise the utility of proprietary tools and which is informed by objective assessment of the relative costs and benefits of individualised resources, indicated a need for further investigation of active learning for CAD systems, discussed on pages 249-273.

Requirements for self-directed learning

The rationale for explicit provision in the instructional model to develop capabilities of trainees for self-directed learning of CAD applications derived from a combination of factors. In the first instance patterns of use for CAD in building surveying practice were changing. On the supply side, meanwhile, the evolution of CAD systems was resulting in more usable technology but subjecting practices to increasingly frequent revision of their software in the process. Amongst effective users of CAD substantial reliance was commonly placed upon self-directed methods for achieving and sustaining knowledge and skills. For the research programme, moreover, self-directed learning was becoming an increasingly significant factor for implementation of the alternative instructional model.

Changing use patterns for CAD

That practices were collectively experiencing changing activity patterns for their various applications of CAD was clearly evident from the 1995 survey. With the exception of measured building surveys, for which use was either static (27% of practices) or increasing (47%), all other CAD functions had a fluctuating pattern of use. In other words some of the sample were using particular CAD applications more, whilst others were using the same applications less intensively (Chart 32, p122). The level of static use ranged from 21%-33%, although scheduling was exceptional in having no static level of use at all. In this context the instructional model needed capacity for enable trainees to become more responsive to changing requirements of their practice and its CAD system(s).

Revised perception of CAD as predominantly usable technology

The improvements achieved in interfaces, capabilities and modus operandi of CAD systems since experiments with Instructional method 2 had emphasised problem solving (pp179-189) were significant for CAD training. Together with the growing user base, evident in the uptake by practices N01-25 (Chart 13, p78), these enhancements necessitated revised perception of CAD as a predominantly usable technology, rather than one fraught with difficulties. Although one or more in a range of obstructions was still likely to occur during application of CAD software, to conceptualise it as a continuum of problems was likely to prove increasingly misleading for learners. The primary task of identifying solutions to problems needed replacing, therefore, with a search for effective methods to achieve requirements regarded as authentic by the trainee and his or her workplace. In this revised understanding problem solving became a subset of satisfying authentic requirements.

Notwithstanding supply side improvements, CAD systems of the types predominantly used in building surveying practices remained complex software constructions, frequently upgraded by their manufacturers. Additional opportunities for their productive application in a particular workplace tend to emerge with their use over time. In such circumstances, staff using CAD need to rapidly extend their knowledge, understanding and ability for applying systems to authentic tasks. Although update training for major software systems is usually readily available, it serves mainly to familiarise trainees in general terms with developments in newly released functions. This provision is usually unsuited to enabling application of such techniques to particular workload in a specific practice.

Observation of skilled users of CAD often indicated discovery learning as an important part of their application strategy. This need was the more substantial and sustained in the context of changing use patterns and revised perception of CAD as predominantly usable technology. The pace of technical developments and changing application patterns in practice meant that users suffered skills erosion as particular applications became dormant. A corresponding need existed to rapidly reactivate previous application capabilities as workload required.

Inadequacies of previous instructional methods

The On-line Expert-Tutor, discussed on pages 221-228, had demonstrated the impracticality of attempting to teach application of CAD systems as a catalogue of commands and procedures. Experiments with Instructional method 2, reported on pages 179-189, emphasised both the inadequacies of many trainees for guided discovery learning, particularly amongst older personnel, and the need to make more appropriate provision for addressing these deficiencies through instruction. Results showed that learning tasks were too wide-ranging in scope and that the brief to find an optimal solution required trainees to function immediately at a much higher level of self-direction than was realistic. In the absence of documentation elaborating on appropriate methods for self-directed learning it was assumed that successful users of CAD either had inherent capabilities, or developed effective methods through trial and error, sometimes over significant periods of time. In response to the factors discussed on pages 241-243 it was proposed that essential methods for self-directed learning could and should be taught explicitly, rather than relying upon inherent capabilities, or ad hoc assimilation of methods whilst working with the technology. The corresponding need was to investigate the form and use of appropriate instructional methods and learning resources. For understandable commercial reasons, however, little evidence was found in the investigation of training providers designing instruction for enhancing the ability of CAD users to bridge gaps in their knowledge and skills by self-directed methods.

Implementing the instructional model

A major benefit of self-directed learning for practices and practitioners is its applicability throughout workplace use of a wide range of CAD scenarios.

Although many trainees observably had limited capabilities for self-directed learning of CAD software, they operated in a working environment where the 1995 survey had found a high incidence of staff development by self-instruction and learning on the job. At one level, therefore, improving capabilities for self-directed learning was simply a means for enabling more effective use of established training methods. However, substantial advantages of self-directed learning were also becoming apparent for the instructional designer, instructor and trainee. Successful self-directed action to overcome authentic obstructions is, by definition, highly relevant learning because the learner knows without doubt that he or she has satisfied a meaningful requirement. Such experiences tend also to increase the user's confidence for making progress by similar methods in future situations. Successful self-directed learning is consequently self-reinforcing. Proprietary applications software, including CAD, was additionally becoming more responsive to discovery learning and observations in class showed that trainees were increasingly willing to proceed on this basis. Inherent limitations identified for both paper-based and computer-based instructional methods of individualising instruction had also increased the significance of adequate capabilities of the trainee for guided discovery learning in order to implement the developing instructional model. For paper-based resources these included the constraints discussed on pages 168-9, 194-6 and 217-21 for accommodating variations in previous experience of CAD. In the case of computer-based resources, self-directed learning was increasingly considered a means of overcoming fundamental technical constraints, for example on knowledge engineering, the high costs of design, production and maintenance considered on pages 223-228 and 234-235.

Discovery Learning Tutor

Rationale

The Discovery Learning Tutor (pp245-249) investigated possible mechanisms for helping trainees develop capabilities to interpret cues in the CAD software system interface, and experiment to confirm or refute their expectations. The experiment formed an initial response to Merrill's (1983, p330) anticipation of the benefits of instruction in "...learner control of appropriate learning strategies." The prototype concentrated upon enabling the trainee to match a required operation with selection from available commands and to anticipate command sequences and procedures for its execution.

The experiment also investigated whether verbal feedback from the software would improve the effectiveness of instructional sequences by comparison to the predominantly visual and textual cues used in the active version of the Procedures Guide discussed on pp235-241. It was assumed that appropriate methods for discovery learning of CAD processes would be taught most effectively by instructional tools embedded in the CAD software system itself.

Experiments with the Procedures Guide had confirmed, however, that greater scope existed for prototyping suitable tools by linking multimedia authoring software to the CAD system than by using its native programming capabilities.

Components and methods

Software components for the prototyped Discovery Learning Tutor are shown in the Fig. 53 (p246) schematic. Instructions in a customised AutoCAD menu used DDE to activate a ToolBook floating window. The trainee then interacted with instructional sequences based primarily upon draggable objects and animated sequences written in OpenScript.

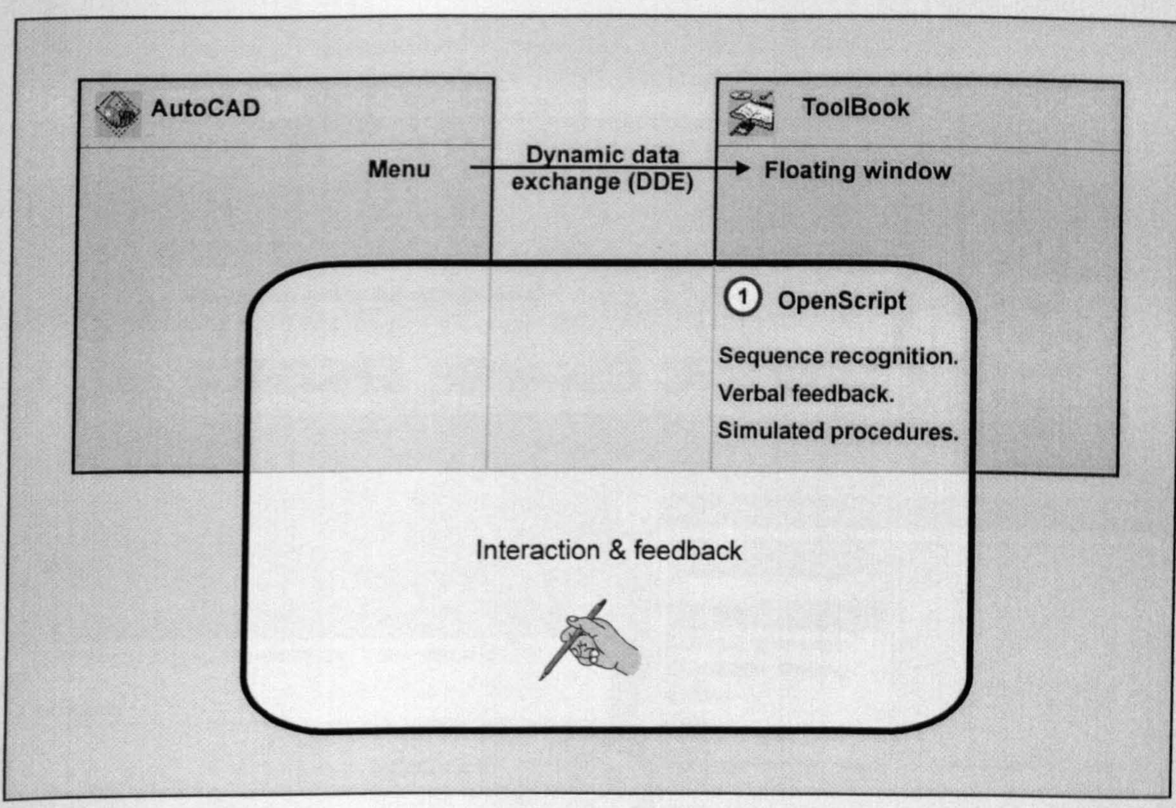

Fig. 53 Software components in the prototype Discovery Learning Tutor

A substantial component of instruction involved draggable objects and sequence recognition. Although the OpenScript code written to assess distribution patterns and provide verbal feedback was necessarily complex its scope was contained within the ToolBook window, thus avoiding a need to monitor activities in the AutoCAD drawing environment.

The trainee first specified a broad activity category of interest from a popup window (ToolBook, Fig. 54①, p247) then chose a specific operation from a list of user-oriented terms as shown in Fig. 54②.

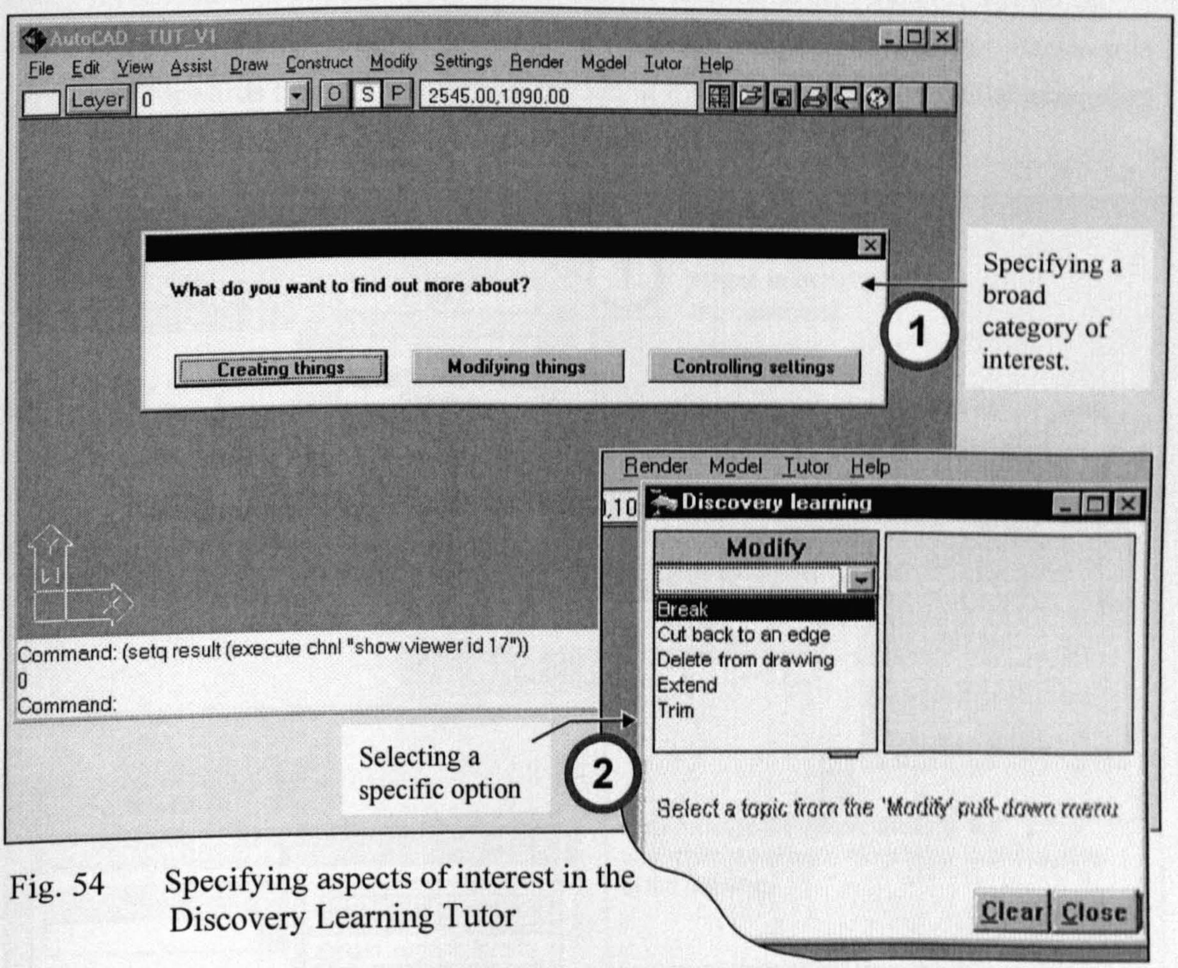

Fig. 54 Specifying aspects of interest in the Discovery Learning Tutor

(Source: c:\icad_rep\report1.tbk; c:\et_su\et_su5c.mnu,.mnl)

The system responded by presenting a random distribution of objects in the ToolBook window labelled with names of AutoCAD commands. The trainee was then asked to find the command label which corresponded with the required function (Fig. 55①, p248). The button click event which occurred as the trainee picked a label spoke the corresponding command name and advised whether it was an appropriate selection. Choosing an incorrect command activated a summary of the function it performed. Identification of the correct command name resulted in a random distribution of labels corresponding to stages of its execution in the CAD system (Fig. 55②). The trainee was then required to reorganise the labels in the correct sequence for the command, starting with placement of the first step at the top of the display. The system spoke a label's text, and automatically re-spaced the sequence, as it was dropped back into the list. When the trainee found the correct command sequence an OpenScript routine spoke the full procedure whilst highlighting the labels in the correct sequence. This audiovisual event was synchronised with an animated representation of pointer operations for the command and the corresponding response of entities in the drawing. The trainee was then able to step backwards and forwards through the demonstration at his or her own pace whilst executing the command in an AutoCAD drawing (Fig. 55③).

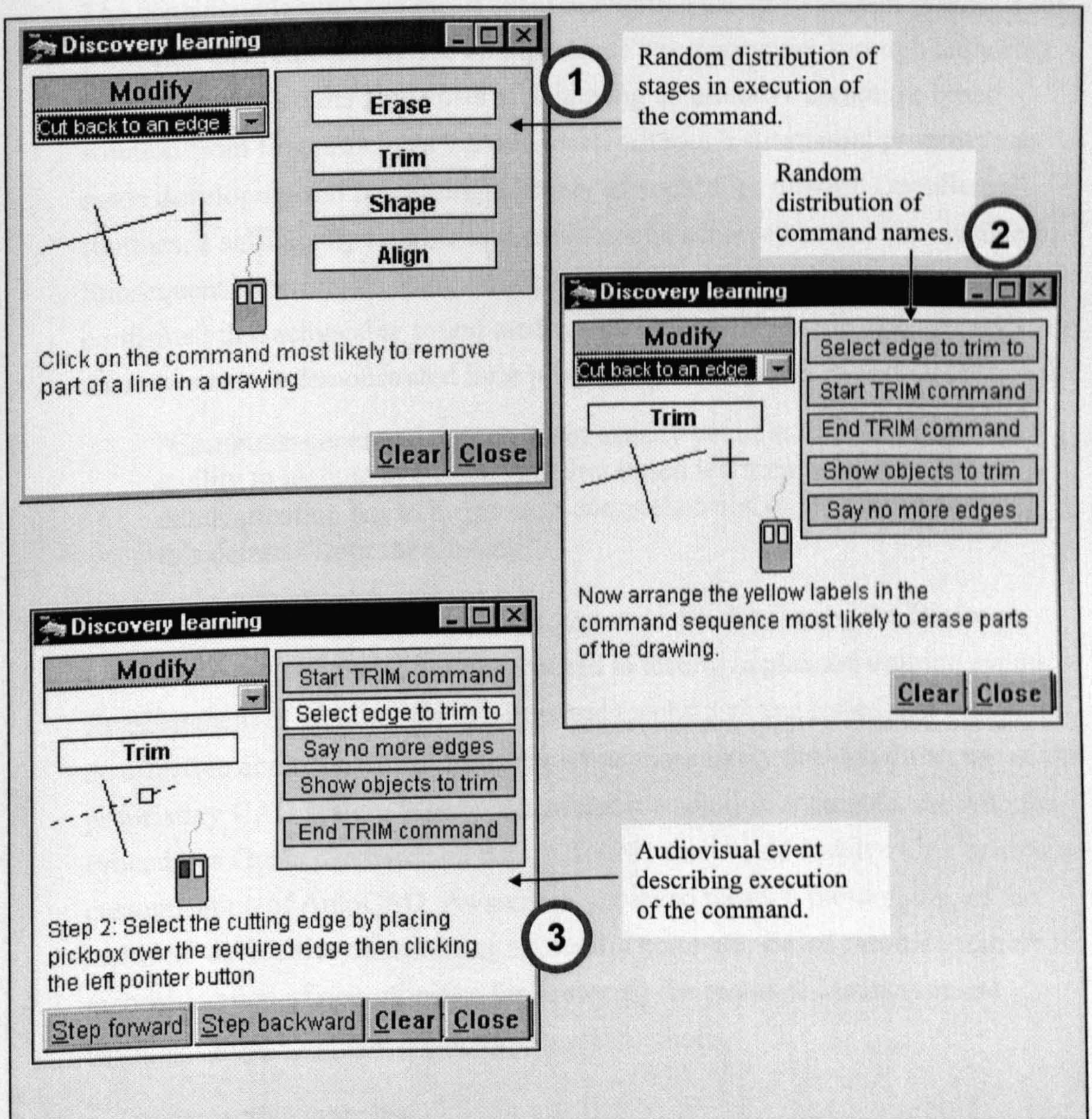

Fig. 55 Key stages in use of the Discovery Learning Tutor

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Results from prototyping the Discovery Learning Tutor

Various deficiencies became apparent whilst developing a prototype for the Discovery Learning Tutor. In practice the underlying concept, as for the On-line Expert-Tutor discussed on pages 221-228, proved too narrowly focused upon execution of specific commands in the CAD system. In consequence the trainee was unlikely to develop adequately generic capabilities. Moreover, the interface and modus operandi of the prototype did not resemble those of the proprietary CAD system sufficiently for methods developed to be adequately transferable. The considerable time and effort spent attempting effective speech synthesis for feedback, and remedial advice on the trainee's performance, through authoring software indicated the high costs of achieving an effective computer-based solution from first principles via this route. Although substantial progress was made developing and processing a library of vocal files through OpenScript routines, a sufficiently flexible tool could not be achieved in the time available. Subsequent experiments using WinSpeech, the available proprietary product, confirmed that achievable sound quality was extensively inadequate. Results via these two routes demonstrated little progress since Ayerst (1987, p60) observed:

> "Computer-generated speech is not usually yet of sufficiently high quality to include in CBL [Computer based learning] programs as too much attention has to be given to comprehension of the speech and this detracts from the content."

The combined effect of problems encountered with developing the Discovery Learning Tutor was that it did not proceed to testing in planned training events. Reassessment of viability for the proposed mechanism suggested that achieving an effective computer-based instruction was more likely through direct use of the proprietary CAD system than by the composite solution attempted. As with the Procedures Guide discussed on pages 235-241 this would involve C++ or similar customisation of AutoCAD. Awareness, achieved through prototyping, of the technical difficulties constraining successful computer-based resources enforced reconsideration of opportunities for achieving the requisite instruction and learning through manual and interpersonal methods.

Instruction for active learning

Revised perception of requirements and provision

A rationale for extending the alternative instructional model to develop self-directed learning capabilities of trainees explicitly could be clearly identified, as discussed on pages 249-254. The initial experiment in providing computer-based instruction through the Discovery Learning Tutor (pp245-249) to achieve this objective, however, demonstrated extensive inadequacies in perception of instructional requirements and corresponding methods. Although the concept underlying the prototype had been too prescriptive and implementation methods overly mechanistic, the experiment helped clarify attributes required of trainees for learning use of CAD systems, and the problems of corresponding instruction.

It had become evident that a predominantly active learning strategy might productively include apparently passive activity. A trainee with substantial capabilities for active learning could, therefore, identify an obstruction at a key point in a learning task and request specific guidance in order to avoid protracted and substantially abortive, experimentation. Alternatively, an obstruction might be experienced by a trainee as an impasse for which external guidance was essential if it was to be overcome. Observation of skilled CAD users showed that, in practice, passive and active methods were often used concurrently and interchangeably to achieve similar learning objectives for CAD software. Landa's (1983) advice that discovery and expository learning are methods for achieving different learning objectives, and not options for achieving the same outcomes, appeared less applicable, therefore, to training for CAD. It had previously been assumed in the investigation that effective instruction for developing active learning would depend upon the ability to initially assess and classifying the learning capabilities of trainees on a scale ranging from externally-directed (passive) to self-directed (active). In this scenario there was a consequent requirement for mechanisms to rapidly reassess a trainee's capability against the same criteria at any point in a learning task, and provide appropriate remedial advice and opportunities for corresponding development. In the revised perception of active learning for CAD, selection and use of more passive learning resources did not necessarily categorise a trainee as a predominantly passive learner. The rationale for classifying methods and resources for learning CAD on a scale ranging from passive to active was consequently rejected. Moreover, the term "active learning" was used subsequently in the research programme to mean self-directed development of CAD knowledge, understanding and practical ability characterised by awareness of alternative routes to learning and the ability to benefit from them.

A strong case had been developing in the research programme thus far to individualise instruction for the learning capabilities of a particular trainee. This approach was increasingly at variance with commercial imperatives and associated constraints of cost and time on production and delivery of corresponding learning resources. Results from prototyping the Procedures

Guide discussed on pages 235-241, indicated potentially prohibitive costs for developing and maintaining such instructional resources. The essential monitoring function discussed on page 234 for the prototyped Mental Modeller would need to be substantially more sophisticated in a computer-based instructional mechanism than originally conceived. Such constraints endorsed the more cost-effective concept of enabling trainees to use existing learning resources rather than attempting to accommodate a range of learning capabilities in purpose-designed computer-based provision.

Revised perception of CAD as predominantly usable technology (pp242-243), albeit still constrained by obstructions at varying intervals with different durations, increased the prospects of trainees achieving what Merrill (1983, p233) described as "appropriate processing" of instructional material. In this approach learners would be enabled to make use of resources that were sub-optimal for the current task either because of their partial nature, or though their design and production for another audience and purpose. Merrill (1983, p328) anticipated training the learner to make decisions about which instructional components to investigate, when and for how long using:

> "... an adaptive instructional management system ... That assists the student to use ... [a] rich array of displays ... It is also possible that students can be taught to use learner control more effectively."

Unfortunately Merrill continued by acknowledging a lack of research on how to implement this adaptive instructional management system, or to teach more effective learner control where such capabilities were inadequate:

> "The research to date has been insufficient to determine the feasibility or best approach for such training."

Recommendations by Dryden and Vos (1994) for generating ideas by recognising patterns, relating discoveries to existing knowledge, and reinforcing solutions as they are found, also appeared applicable to active learning for CAD. In this connection the range of applications software installed by the 1995 sample of building surveying practices suggested substantial scope for utilising experience with other systems to inform development of CAD capabilities through active learning (Table 19, p252).

Application	% of practices Y01-25	% of practices N01-25	N01-25 relative to Y01-25
Word processing	100%	100%	No change
Accounting	63%	50%	-26%
Spreadsheet	74%	31%	-139%
Database management	63%	25%	-152%
DTP	21%	25%	+16%
Office management	11%	6%	-83%
E-mail	5%	0%	Not available in N01-25
CAD	100%	38%	-163%
Specification writing	63%	38%	-66%
Project planning	32%	25%	-28%
Planned maintenance	0%	6%	Not available in Y01-25
Structural survey	0%	6%	Not available in Y01-25
Engineering	0%	6%	Not available in Y01-25
Briefing analysis	0%	6%	Not available in N01-25

Table 19 Applications software in the Y01-25 and N01-25 sample of building surveying practices at 1995

In addition to CAD, practices in the Y01-25 sample had a total of six technical applications and seven standard office systems with an incidence ranging from 5% for E-mail to 100% for word processing. Practices N01-25 had installed a total of 12 different types of software at 1995. Three of the technical applications involved were not available in Y01-25, and four of the seven standard applications had a lower incidence than in Y01-25. Only DTP had a higher incidence in practices N01-25 then practices Y01-25. None of the N01-25 sample had e-mail at 1995. Conversely, three of the 10 technical applications available in practices Y01-25 were not available in N01-25 (Table 19).

Investigation of learning resources in the research programme was consequently refocused. Consideration of potentially expensive, purpose-designed computer-based resources was superseded by investigation of robust, generally applicable methods of learning from ready-made, general-purpose, proprietary resources and the CAD system itself. Scandura (1983, pp237-38), amongst others, acknowledged the gap between learning theory and instructional practice. Subsequent R & D in Phase 5(2) attempted to clarify the nature of effective active learning for CAD, and to investigate provision of corresponding instruction by which it might be developed. This work synthesised observations, concepts, methods and recommendations from a variety of sources. Observations of trainees working in the classroom with Instructional methods 1-3 (pp157-221) were reviewed. Relevant prescriptions were sought in published theories, and observation of the methods of expert users of CAD, and discussed in a commercial context. In a parallel investigation the author examined his own processes for learning CAD software. Whilst it was reasonable to assume that expert CAD users who successfully undertook active learning of CAD were bridging the gap between learning theory and instructional practice they tended, as with many areas of technical expertise, to be unaware of the extent to which reliance was placed upon unconscious cognitive strategies. As a result it proved difficult to obtain sufficiently detailed explanations of productive methods to inform algorithms by which trainees could assimilate similar techniques. Likewise, those instructional theorists investigated (Merrill; Dryden and Vos), failed to provide specific insights to methods for enhancing a trainee's inherent capacity for active learning. Endorsement was found in Landa (1983, p59), however, in the absence of published guidance on its essential nature, or how to implement it for CAD for using the author's own learning processes to establish key features of an active learning methodology for CAD software systems:

> "What are the sources of a teacher's knowledge of instructional programs / and or processes? The first of them (historically and often ontologically[1]) is one's own and other teacher's practical experiences of what happens (or what outcomes appear) if one performs some instructional actions under certain conditions."

---

1 Ontological: The set of entities presupposed by a theory.

Three contexts for active learning

Subsequent analysis of the aspects discussed on pages 254-263 identified workplace requirements for active learning of CAD in three contexts:

1. Mapping essential components, structures and mechanisms of the CAD system.

2. Resolving or circumventing obstructions to implementing an existing production strategy.

3. Improving an existing production strategy, or identifying a new one.

These contexts appeared to correspond with Merrill's (1983, pp281-2) requirement in a learning management system for self-directed activity to perform in relation to facts, concepts, principles and procedures across the three domains of:

1. Know / remember.

2. Use.

3. Find.

However, as Reigeluth (1983, p282) observed:

> "It should be noted that Merrill has not yet explicitly developed a model or models for the 'find' level (i.e., the cognitive-strategies domain)."

Active learning Context 1 also responded to Landa's advice (1983, p203) to deal with specific, predefined procedures at a basic level for newcomers and users of routine procedures. Context 3, meanwhile, corresponded with his recommended emphasis upon development of new procedures for strategic and innovative applications.

(Next page 256)

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Active learning strategy for Context 1

Synthesis of results after due consideration of the sources identified on page 253 suggested that active learning for Context 1 to map essential characteristics of a CAD system is a four step iterative process,summarised in Fig. 56, page 257. In Step 1 the learner interacts with experienced users, the CAD software system, paper-based and computer-based learning resources, as necessary, to form initial overviews of three interrelated aspects. The first aspect concerns the types of drawing or model required from, and expectations of, the CAD software system. Secondly the learner attempts to clarify associated performance characteristics of the software system. In Step 3 the learner anticipates events in a corresponding production strategy for the required drawing or model. Whilst investigating the first three aspects the learner scans the specified resources and applies a scope test to each instance found of potential significance. The scope test involves analysing the current instance and conducting ad hoc experiments, as necessary, to establish if it can be explained in terms of known principles, concepts, or procedures. Where the current instance can be wholly explained in this way then the perceived scope of corresponding principles, concepts or procedures is modified accordingly. Where the instance can only be partially explained in this way, or not explained in terms of existing knowledge and understanding at all, then further analysis is undertaken. Secondary analysis involves establishing whether or not the current instance can separately, or with previous instances, be used to either modify understanding of known principles, concepts or procedures, or assimilate those which are additional to current understanding. Where consideration of the instance indicates that it can be used to modify or extend awareness then understanding of known principles, concepts and procedures is adjusted accordingly. Alternatively the current instance is registered as an exception with potential significance for future understanding and use of the CAD system. Throughout the investigation and analysis described above for Step 1, notes and diagrams are made as necessary to clarify requirements and corresponding explanations. Quick, practical experiments are also undertaken to test understanding of concepts and interpretations of software functionality.

In Step 2 of the active learning strategy for Context 1, results from Step 1 are collated and assimilated. Learning methods are modified in response to results achieved. Perception of requirements, expectations of the CAD system and events in the anticipated production strategy are reviewed and revised.

Step 1

Interact with experienced users, the CAD system, paper-based and computer-based learning resource(s), as necessary to form initial overviews of the:

- Type(s) of drawing or model required from, and expectations of, the CAD system.
- Performance characteristics of the software.
- Anticipated events in a corresponding production strategy.

Scan resources concurrently and apply the scope test to each instance found of potential significance. →

Make:

- Notes, diagrams to clarify requirements and corresponding explanations.
- Quick practical experiments to test understanding of concepts and interpretations of software functionality.

Step 2

Collate and assimilate results achieved from Step 1 and:

- Modify learning methods accordingly.
- Review and revise perception of requirements, expectations of the CAD system and events in the anticipated production strategy.

Step 3

Scan and experiment with menus, dialogue boxes and toolbars to gain, reinforce and extend awareness of interfaces, functions and procedures potentially relevant to the production strategy anticipated in Step 1.

Apply scope test to each instance found of potential significance. →

Step 4

Collate and assimilate results achieved from Step 3 and modify learning methods accordingly.

Iterate Steps 1-3, as necessary, to resolve inadequate knowledge and understanding.

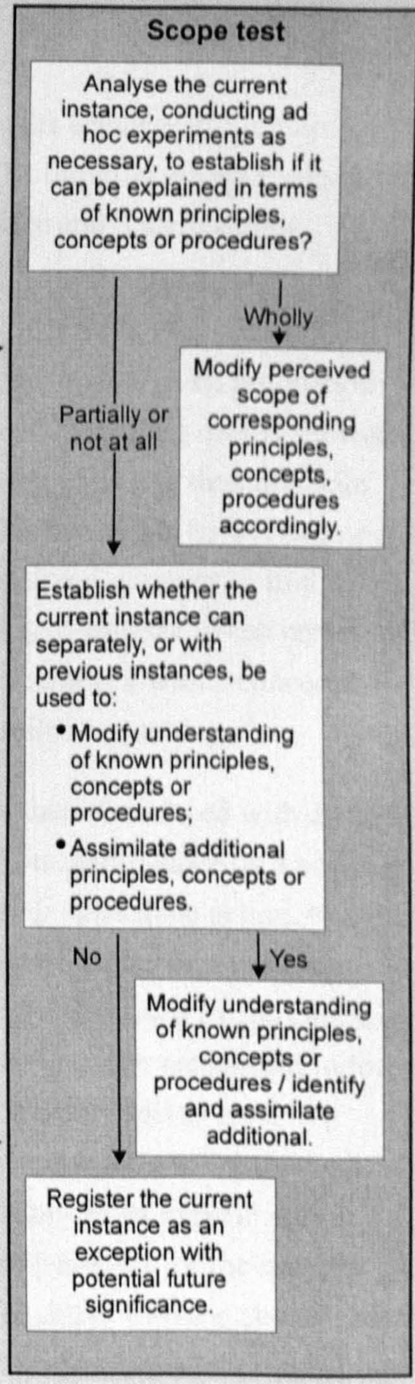

Fig. 56 Active learning strategy for Context 1: Mapping essential characteristics of the CAD system

Step 3 requires the learner to scan and experiment with menus, dialogue boxes and toolbars to gain, reinforce and extend awareness of interfaces, functions and procedures potentially relevant to the production strategy anticipated in Step 1. The scope test described above is reapplied to each instance of potential significance as it is found.

In Step 4 the learner collates and assimilates results achieved from Step 3, and modifies his or her learning methods accordingly. Iteration is then made of Steps 1-3, as necessary, to resolve inadequate knowledge and understanding.

Active learning for Context 2

Although ideally a trainee comprehensively understands a given production strategy at the start of a learning task, observations in training events showed a far more frequent requirement to identify a starting point and then maintain momentum for learning through a series of production stages by overcoming intervening obstructions to progress. Methods enabling a trainee to find a suitable individual starting point, then overcome any impasse which prevented progression had relevance for active learning in Context 2 which concerns resolving obstructions to applying an existing production strategy.

Observations of experienced CAD users showed that when faced with difficulties using a CAD system they may variously classify its significance on a scale ranging from a small obstruction possibly requiring immediate action, to a full impasse preventing further progress with the current application until resolved. Selection between routes to achieving a solution is influenced by the category into which the obstruction has been placed. A need may be recognised to locate exposition of a fundamental concept to help decide how best to resolve a particular application problem. A search may be undertaken to locate the best available explanation in proprietary resources, followed by experiments to discover and assimilate implications of the general concept for the specific current problem and requirements. Instruction for active learning should respond accordingly by developing the trainee's capabilities for accurately classifying the significance of obstructions to progress, then selecting and applying appropriate methods for overcoming them. The basis for relevant algorithms and heuristics is summarised in Steps 1-7, Fig. 57 (p259).

Step 1 : Rapid iteration of:

1.1 Establishing if the obstruction(s) can be bridged by modifying existing application methods, or using available alternatives.

Progress checks →

1.2 Investigating unfamiliar language and terminology.

Progress checks →

1.3 Prompting for, and interpret, cues and other indicators.

Progress checks →

1.4 Inferring explanations and potential solutions.

Progress checks →

1.5 Scanning available sources for guidance or pre-defined solutions.

Progress checks →

Step 2 : Sustained analysis:

2.1 Scan available sources to locate relevant guidance, placing custom bookmarks in on line help. Analyse and apply logic of found or given instance(s) to resolve the current obstruction. (Step 2 involves more formal analysis of a whole worked example by comparison to Step 1 which uses selected fragments of guidance to supplement ad hoc experimentation.)

Progress checks →

Step 3 : Periodic review

3.1 Work concurrently on another stage or sub-task in the production strategy and cycle through Steps 1 and 2 periodically to review remaining obstruction(s) and potential solutions.

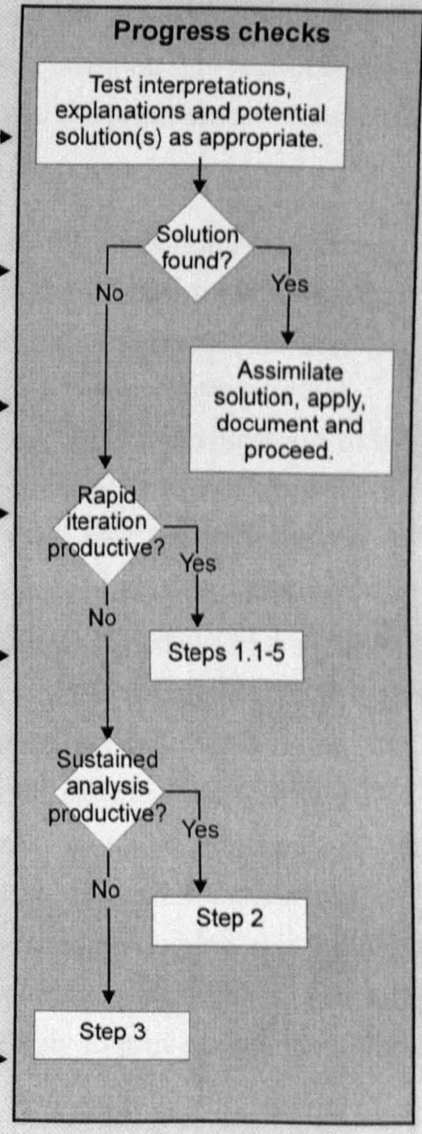

Fig. 57 Active learning for Context 2: Resolving obstructions to applying an existing production strategy

Analysis and experiments in Phase 5(2) indicated that instruction for active learning in Context 2 should be based upon predefined classes of authentic obstruction relevant to the drawing type and activity being undertaken, and specific to the CAD system, without initial overall assessment of the trainee's existing active learning capabilities. Mechanisms would also be required for identifying additional classes of obstruction and corresponding instructional resources as understanding of active learning, and the requirements of trainees and workplaces, develop.

Active learning for Context 2 to resolve obstructions in applying an existing production strategy is a three step cyclical process. In Step 1 rapid iteration occurs of five activities interspaced with checks for progress and the need for corresponding action. The learner first establishes whether obstruction(s) encountered can be bridged by modifying existing application methods, or by using available alternatives. The second activity involves investigating unfamiliar language and terminology. Activity three requires the learner to prompt the CAD system for cues and other indicators, and then interpret those received. In activity four the learner attempts to infer explanations and potential solutions from results obtained up to this point in the investigation. Activity five involves scanning available sources for guidance or predefined solutions. The progress checks interspaced between activities 1-5 start with establishing whether a solution has been found to the current obstruction. Where a solution has been identified then the learner assimilates, applies and documents its prescriptions, before proceeding with the established production strategy. Where a solution remains to be identified then the learner assesses whether continuing with rapid iteration of activities 1-5, above, is likely to prove productive. Where positive results are anticipated the learner continues looping through Steps 1.1 - 1.5. Alternatively a decision is made on whether sustained analysis of the obstruction is a more productive option. Where Step 2 indicates a stronger possibility of progress the learner proceeds with the sustained analysis in Step 2. Alternatively the obstruction is dealt with through periodic review in Step 3. Step 2 requires the learner to scan available sources to locate relevant guidance, placing custom bookmarks in on line help files to mark relevant items. The logic of instances found is analysed and applied in an attempt to resolve the current obstruction. Step 2 requires more formal analysis of a whole worked example by comparison to use of selected fragments of guidance for supplementing ad hoc experimentation in Step 1. The progress checks described above for Step 1 are made at appropriate intervals and may, if productive, route the learner back into rapid iteration of the five associated activities. In Step 3 the learner periodically reviews the obstruction which initiated a search for solutions by cycling through Steps 1 and 2, above, to review remaining difficulties and potential remedies whilst working concurrently on another stage or sub-task in the production strategy.

Active learning for Context 3

Active learning for Context 3 (Fig. 58, p262) responded to results of experiments with Instructional method 2, reported on pages 181-210, in which trainees had been required to identify a production strategy for their target drawing or building model at the start of a learning task. Results had shown that expecting trainees to identify an optimal production strategy for output they had yet to produce, using techniques of which they had limited or no experience, was unrealistic. Further investigation was therefore needed of active learning concepts, principles and techniques to identify or improve a production strategy for use of CAD. Subsequent observations in undergraduate classes[1] of application strategies proposed by trainees indicated that understanding of the required processes, their sequencing and interrelationship, typically developed gradually and unevenly.

Active learning for Context 3 to identify or improve a production strategy is a five step process, which draws selectively upon the methods described above for Contexts 1 and 2. In Step 1 the learner either states or restates required characteristics of the target output from the CAD system. Definition is made in terms of the type of drawing or model required, information sources from which it will be produced, qualitative attributes of output as apparent in template files or hard copy, and the required formats for hard copy and digital result. In Step 2 the learner reviews output requirements, specified in Step 1, in relation to known capabilities of the available CAD system, personnel using the software, existing application methods and time available in which to make the application.

1 De Montfort University undergraduate modules CNST1005 : Spatial Information Systems; CNST2004 and CNST2008 : Design and Construction Processes Studios 3 and 4.

Step 1

(Re-)state characteristics of the target output in terms of:

- Type of drawing or model.
- Source(s).
- Qualitative attributes as apparent in template(s).
- Hardcopy and digital output formats.

Step 2

Review output requirements in relation to known capabilities of the available:

- CAD system.
- System user(s).
- Application methods.
- Time resources.

Identify a corresponding interim production strategy in terms of:

- An optimal sequence of stages, sub-tasks and software functions.
- Inadequacies and unknowns apparent prior to application.

Step 3

Make selective use of active learning techniques for Context 1 to investigate unexplored capabilities of the software system with potential for resolving inadequacies and unknowns from Step 2.

Step 4

When either an optimal production strategy has been identified, or the time limit for its consideration has been reached:

- Apply identified methods.
- Monitor the provisional strategy for defects and enhancement opportunities.
- Use active learning techniques for Context 2 to overcome obstructions which may occur.

Step 5

Follow up on initial implementation by repeating Steps 1-3 as necessary to review and revise the new or enhanced methods.

On verifying effective development, document the new or improved production strategy for dissemination as appropriate.

Fig. 58 Active learning strategy for Context 3: Identifying or improving a production strategy

These factors are then assimilated to identify a corresponding interim production strategy in terms of an optimal sequence of stages, sub-tasks and software functions. The learner is also required to identify inadequacies and unknowns apparent prior to application of the interim strategy. In Step 3 the learner makes selective use of active learning techniques for Context 1 (Fig. 56, p257) to investigate unexplored capabilities of the software system with potential for resolving inadequacies and unknowns from Step 2. Step 4 is undertaken when either an optimal production strategy has been identified, or the time limit for its consideration has been reached. At either point the learner uses the CAD system to apply the identified methods whilst monitoring the provisional production strategy for defects and opportunities to enhance its sequence. Active learning techniques for Context 2 are used, as necessary, to overcome obstructions which may occur in this process. During Step 5 the learner follows up initial implementation of the application strategy by repeating Steps 1-3, above, in review and revision of the new or enhanced methods. Once developments in methodology have been verified the learner documents the new or improved production strategy for dissemination, as appropriate in the practice.

Prototype for a computer-based Active Learning Tutor

Prototyping the Discovery Learning Tutor, and subsequent review of requirements, indicated that manual and interpersonal instruction were likely be more effective than computer-based methods for instruction in active learning. However, manual and interpersonal methods were constrained by the high costs involved and limited availability of the trainee and instructor for instruction and learning, particularly in smaller practices. Investigation of mechanisms for automating tuition in active learning was also likely to result in more rigorous analysis of requirements and the processes for instruction. For these reasons further investigation was undertaken of computer-based methods. In doing so it was accepted, however, that further research might indicate that for the interim period manual and interpersonal methods provided the only viable means of instruction.

With improving interfaces and integral support for end users in proprietary CAD software the logical primary resource for computer-based instruction, assessment and remedial advice to guide trainees in developing active learning capabilities became the CAD system itself. Use of in-built and other proprietary software tools for this purpose would reduce the costs of production and maintenance since upgrades affecting CAD system interfaces and functionality are also likely to affect the relevant software tools. It was apparent, however, that monitoring the trainee's activity, diagnosing deficiencies and providing appropriate guidance on active learning through proprietary CAD software was impracticable within the limited resources of the research programme. Notwithstanding the preferred option for evaluating and diagnosing the trainee's active learning capabilities in the CAD software, initial experiments demonstrated insufficient control over activity tracking to progress with an embedded learning resource of the type envisaged. Attention was focused as an expedient instead upon a purpose-designed application to fulfil the required function. Use of a purpose-built microcosm was also consistent with Patrick's advice (1993) that if the training mechanism is comparable in psychological terms to the end application then effective training can be achieved using devices which have limited physical resemblance to the end state in which the trainee will operate.

The prototype Active Learning Tutor was developed firstly to investigate the viability of computer-based instruction for Steps 1-4 in active learning Context 1, summarised in Fig. 56 (p257), and for Steps 1.1 - 1.5 in Context 2, shown in Fig. 57, p259. The process started by the Tutor software specifying a category of question or problem then assessing the trainee's ability to locate and test corresponding explanations and solutions in on line help files or hard copy sources for clarifying unfamiliar language and terminology within a specified time limit. The prototype was secondly intended to provide an appropriate environment for the trainee to apply the explanations and solutions found.

The essential components and processes for the prototype Active Learning Tutor are summarised in Fig. 59. Instructions in a customised AutoCAD menu used DDE to activate a ToolBook floating window presenting a microcosm of the full CAD system and resources for instruction, learning and assessment. A conventionally structured online help file was supplemented with macros relaying the trainee's activity back to the tutor software (Fig. 59①) for analysis.

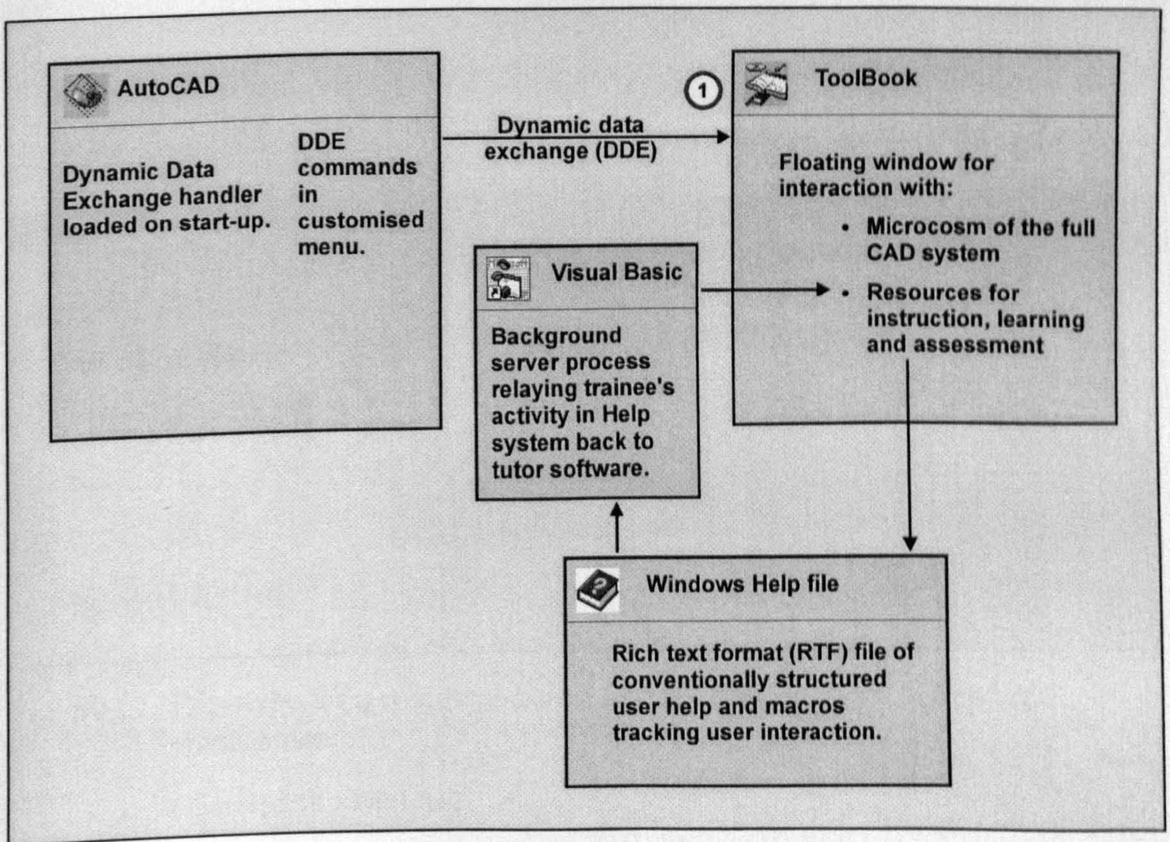

Fig. 59 Schematic for a computer-based Active Learning Tutor

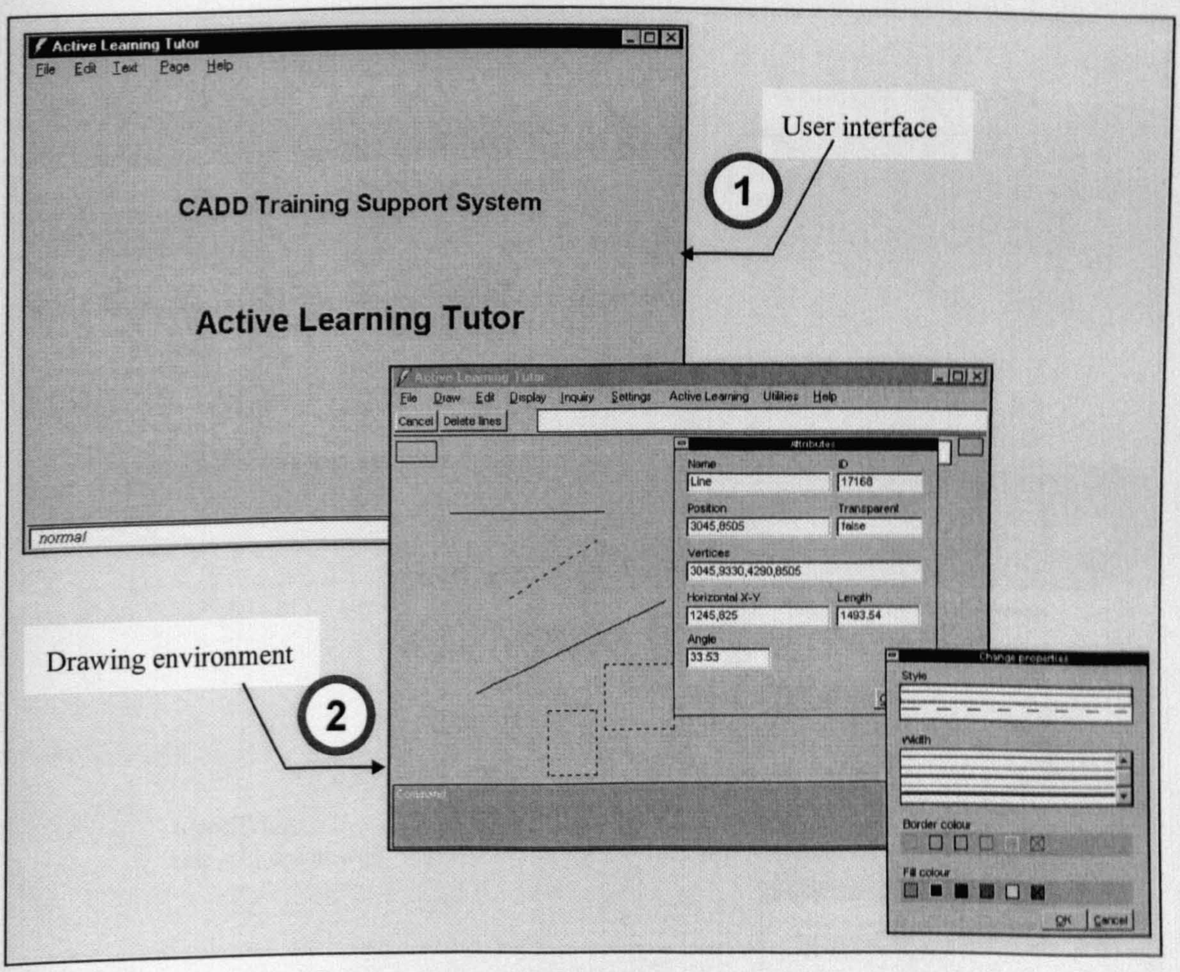

Fig. 60 Prototype for a computer-based Active Learning Tutor : Drawing environment

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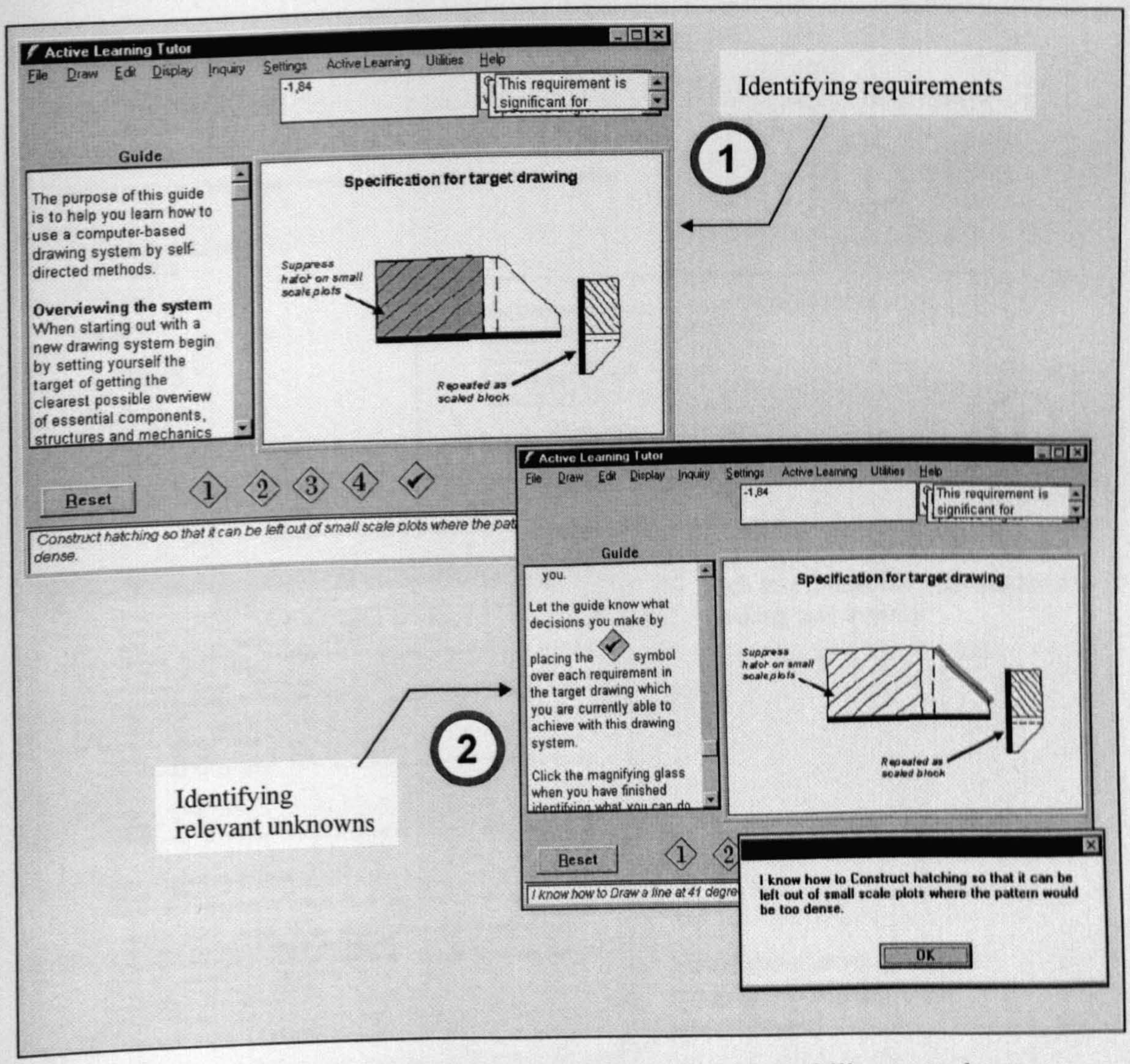

Fig. 60a Active Learning Tutor: Prototype for developing ability to analyse a target drawing (for Step 1 in Context 1)

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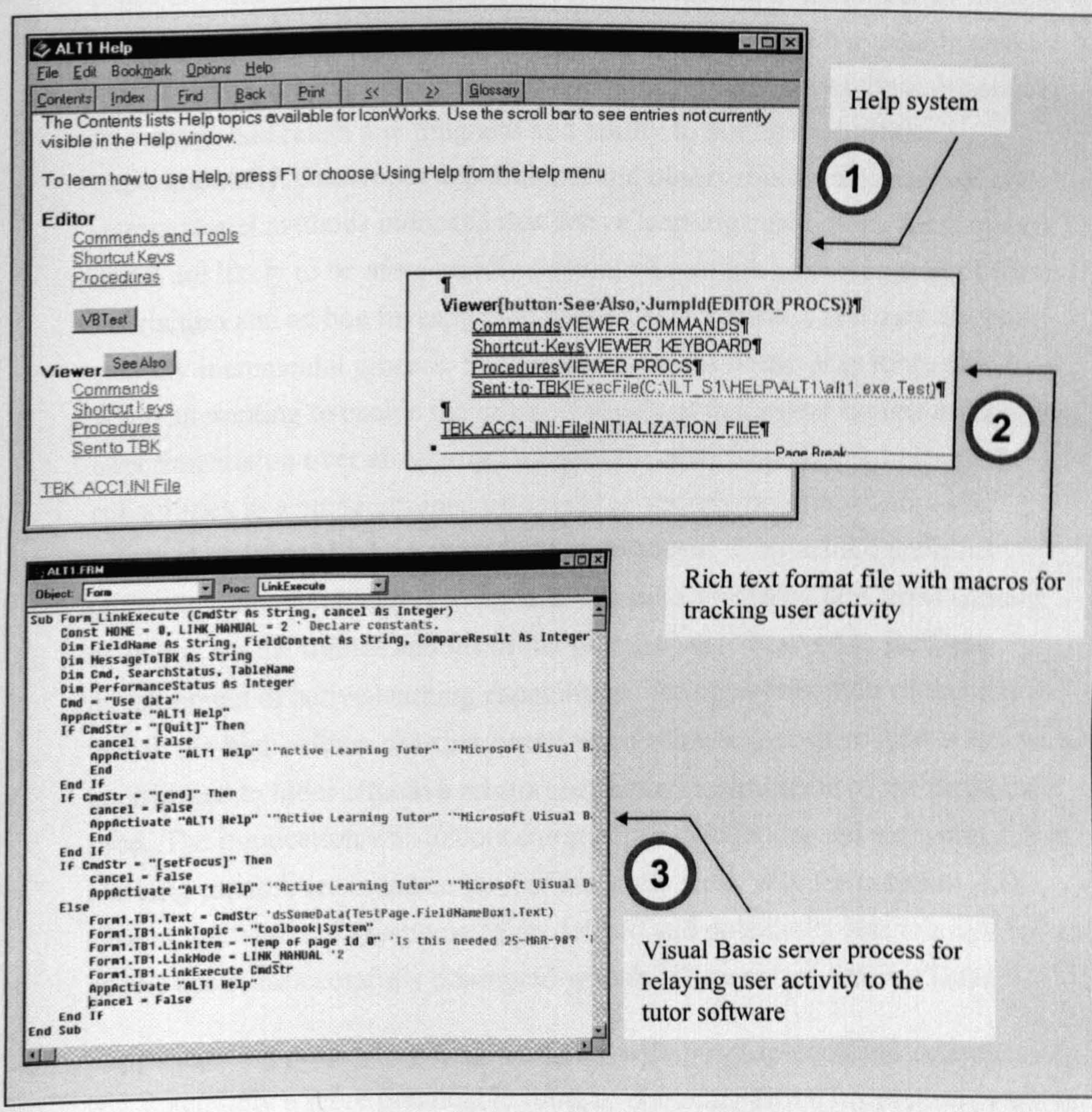

Fig. 60b Active Learning Tutor : Prototype for monitoring and diagnosing user activity in on line help.

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Conclusions on developing active learning capabilities

Proposals for active learning in the three contexts discussed on pages 254-263 improved significantly over the concepts underlying the prototype Discovery Learning Tutor discussed on pages 245-249.

Synthesis of results from investigating the various sources described above indicated that the attributes and processes required for effective active learning to use CAD systems included a willingness and ability to clarify perception of the required outcome(s), to recall previous solutions, and to anticipate or infer new solutions. It was also frequently necessary to rapidly search available resources for solutions, compare procedures found with perceptions of those considered necessary, and retain a willingness and ability to attempt solutions experimentally. Classroom experiments and observations using manual and interpersonal methods indicated that active learning capabilities for Contexts 1 and 2 are likely to be more rapidly developed through a combination of formal instruction and ad hoc investigation of the CAD software, and may not be a steadily incremental process. Such instruction was observably more effective when attempting to enable the inherent ability of individual trainee to learn by experimentation over an appropriate period, rather than aiming to teach the capabilities in a predetermined timescale as entirely new knowledge and practical abilities of which the trainee is presumed to have little previous understanding or capacity. Basing instruction in a learning task upon content authentic for the trainee and his or her practice was observed to facilitate development of active learning capabilities. The apparent origin of this effect was in the high relevance experienced when achieving positive results and which contributed to more effective reinforcement and assimilation of the methods used. The implication was to concentrate upon developing and assessing active learning capabilities in the context of authentic work with the current CAD system, rather than in response to predefined and potentially less relevant targets, as had been unsuccessfully attempted with the Discovery Learning Tutor.

Supplementing proprietary CAD software with purpose-designed external tools was essentially a more practicable route to computer-based instruction in active learning than attempting to customise the base CAD package itself. A purpose-built microcosm of a CAD system representing essential features of the full interface, environment and controls provided considerably more scope for computer-based instruction in algorithms and heuristics to develop knowledge, understanding and practical capabilities for active learning than had been achievable in experiments with the Procedures Guide (pp235-241) to deliver instruction through proprietary CAD software. However, refining the initial prototype (pp263-268) became too technically demanding for completion within the research programme. It was also apparent from classroom observations that resources designed and produced for developing active learning would normally be useful for only limited periods by individual trainees since the transition from a predominantly directed to self-reinforcing active learning may require few catalytic events.

Although technically feasible, custom-designed digital instructional resources for active learning with the characteristics prototyped are unlikely to be of substantial use to trainees already able to utilise a CAD software system and its integral support for discovering additional knowledge, understanding and practical abilities. This assessment suggested further investigation of Merrill's (1983, p282) advice concerning achieving an appropriate scale for an intervention:

> "... for a relatively difficult objective in relation to student ability and experience, a relatively rich version of the appropriate model would be used, whereas for an easy objective a lean version would be prescribed."

As with earlier phases of R & D, analysis for, and results from prototyping computer-based instructional resources provided useful insights to improve the effectiveness of interpersonal techniques for achieving the same learning objectives. In consequence research and development concluded in favour of initially providing instruction for active learning in Contexts 1 and 2 through a combination of computer-based, manual and interpersonal techniques. For this purpose computer-based resources should include the proprietary components in, and associated with, a CAD system, and purpose-designed applications. Instruction for active learning in Context 3, namely identifying or improving a CAD production strategy, was acknowledged as an extension of Stage 2.1 in the model and should consequently be dealt with separately from active learning for Contexts 1 and 2.

The need was apparent for creating and maintaining conditions conducive to development of active learning capabilities namely:

- A non-threatening environment in which to experiment.
- Presumption for an experimental approach to learning CAD applications.
- Mutual support amongst trainees.
- Regular opportunities for review and revision of requirements, methods, progress and achievement.

- A complementary relationship between individual and group work.
- Extensive opportunities for trainees to observe examples of effective active learning and appreciate resulting benefits.
- Provision for trainees to contribute to extension of active learning methods for Contexts 1-3.

The essential features of a potential strategy for instruction to develop active learning capabilities included:

- Initial assessment by the instructional designer of the trainee's active learning capabilities with the CAD system including identification of authentic obstructions and discussing potential solution routes with the trainee.
- Provision of appropriate instruction and guidance in active learning combining individualised use of resources in response to the trainee's learning preferences, and generic methods for developing more active learning with the CAD system.
- Reassessment by practical testing and discussion with the instructor of the trainee's active learning capabilities for CAD.
- Responding to deficiencies in the trainee's performance with remedial guidance.
- Reassessment of the trainee's active learning capabilities through practical testing and discussion with the instructor.

Regulating active learning

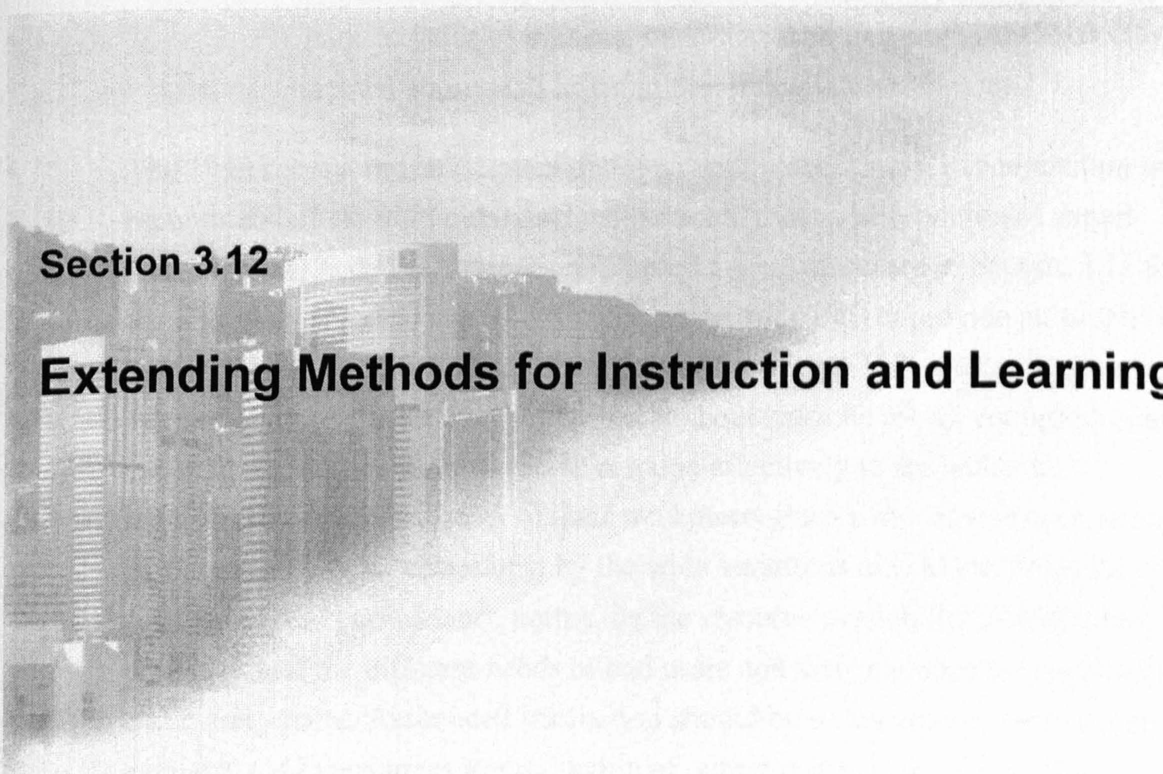
Whilst developing capabilities for active learning in Contexts 1-3 is important for effective use of CAD, a corresponding ability to acknowledge when they are not the most appropriate route to resolving obstructions in the workplace is also important for efficient practice. Where either low priority or lack of resources for upgrading or replacing deficient hardware and software mean that human ingenuity and perseverance are the primary factors in overcoming incompatibility problems then practices should have the capacity for working around such constraints. Practices without the knowledge and skills to function in this way should develop them. They also require the ability to distinguish viable limits of work around remedies and the need for more fundamental solutions involving external advice, expenditure to upgrade or replace system components. Trainees should, therefore, be able to distinguish between the adequacy of local knowledge, understanding and skills, and requirements to seek third party advice on procedural problems where consultation with other staff in the practice may not suffice.

Further research

At the close of the investigation described on pages 241-272 a clear need existed for further research and development to improve theories of active learning for the use of CAD systems. It would also be necessary to review and revise the basis for future inquiries.

Primary references for investigating active learning in the work undertaken were the personal experience and methodology of the author. A feature of this experience had been an initial imperative and subsequent preference for self-instruction in applications software. Whilst evidently productive this approach may have limited perception of the purpose, design and mechanisms proposed for active learning tuition. Insufficient time was available in the research programme to assimilate work published more recently in this domain, including that by Pettigrew and Elliott (1999). Although the latter predominantly considered instruction for standard office software including word processing, spreadsheet and database systems, their recommendations may have important implications for self-directed learning of CAD software applications. Merrill's observation (1983, p328) on the inadequacy of research for instruction in more efficient learner control endorsed the case for self-experimentation to an extent. The need remained nonetheless for further investigation of the nature and mechanisms, incidence, significance and techniques of active learning amongst a more representative range of end users. In terms of substantive content this work would beneficially include initiatives to enhance understanding of the need for active learning and the capabilities required of trainees for progression by this route. Results from the current investigation suggested that further work should focus upon methods for uncovering and developing the inherent active learning capabilities of a trainee over individually appropriate periods. It was also clear that there should be no presumption against use of relatively low-tech solutions, for example paper-based worksheets of the type developed for Instructional method 3 (pages 210-221). Further R & D should seek instead to identify and test a set of principles and techniques for effective interaction between the instructor, trainee, learning resources and the CAD software or its simulation. An early task would be to review the adequacy of the three contexts specified for active learning in the current investigation. Mechanisms proposed for instruction and assessment to develop active learning for Context 2 in relation to specified requirements particularly required review and development. Extension of the classification system for obstructions in this context was considered substantially beyond the scope of the current research programme. Further consideration should also be given to the apparent lack of awareness amongst skilled CAD users about the extent to which they rely upon active learning, and the methods used for this purpose.

Further research and development of active learning should also involve more structured testing against the characteristics summarised in Figs 56-58, (pp257-262), to assess the effectiveness of alternative mechanisms for developing required capabilities. Such assessment would need following with clearly defined mechanisms for responding to the results obtained. A productive method would include identification of an optimal combination of methods and learning resources, including specification of potentially effective interpersonal techniques derived from analysis for computer-based methods. The assessment process should compare and contrast proposals resulting from further research of computer-based methods for developing active learning at a conceptual and operational level with those evident in commercial alternatives, for example Autodesk's Inside Track (1996) and Release 14 Learning Assistance (1997).



Section 3.12

Extending Methods for Instruction and Learning

Revised provision for training needs analysis, planning and design in Stages 1.1 - 1.4 of the alternative instructional model

Factors identified in the research programme that vary substantially between practices, and which may combine to limit the effectiveness of existing training interventions for use of CAD included:

- The structure of practices and their workloads.
- CAD strategies, management and application methods, and the resources available for their implementation, including the origin and version of CAD systems.
- Requirements of a practice for the CAD performance of individual staff.
- Characteristics of trainees, including their existing CAD knowledge, practical ability and learning preferences.

The 1995 survey and subsequent dialogue with practitioners, in conjunction with recommendations from published instructional theory, observation of expert users of CAD and CAD trainees reinforced a need discussed in Section 3.11 for the alternative model (Fig. 34, Model Version 1d, p206) to provide an adaptive training shell. This shell should be independent of the CAD system in place and the particular applications of end users. It should also be robust enough to enable individual practices and trainees to respond effectively to the authentic requirements and constraints of their workplace. Such a model was necessitated by developments in technology, by the wide variations in CAD strategy, local procedures and performance norms, by the resource availability of individual practices, and the different needs of end users and their methods for application and management. Associated instruction should be based upon application of available CAD resources to production of output that is authentic for the individual practice, regardless of the normal classification of the software used or of the output to which it is directed. Given those characteristics of building surveying practice discussed in Sections 3.2. - 3.8.4 on pages 58-117, therefore, CAD training needed to reconcile conventional use of CAD software as its manufacturers intended, or authorised trainers interpreted, with commercially expedient application to components of local workload.

Development of alternative methods for instruction and learning to service variations in the characteristics of trainees, described in pages 221-273, relies upon effective analysis of needs, followed by planning and design to deliver appropriate combinations of learning tasks and associated resources. Provision should be responsive to those problems identified by the sample with existing training interventions. It should, moreover, accommodate use of add-on software as integral components of a practice's CAD capability. A primary requirement would be responsiveness to the diversity of CAD application strategies amongst practices, and changing patterns of use for the technology. Corresponding variations in learning objectives could only be identified accurately through practice specific analysis of training needs, followed by staff development programme(s) tailored to the working practices, available software and commercial requirements or constraints of individual workplaces. The training needs analysis, planning and design implied by these imperatives was considerably more detailed than that evident amongst the 1995 survey sample.

Provision in Stages 1.1 - 1.4 of the alternative instructional model should be capable of achieving priorities of the sample for skills development, including increased use of CAD by professional staff. Analysis of needs for CAD training should also deal effectively with opportunities and constraints of developing ICT environments, including increasing provision and use of local area networks. They should also address the specific technical developments for display and manipulation of CAD data files over the Internet and the World Wide Web. The implications of advances in technology for CAD training could be demonstrated by reference to the relatively low uptake of networked CAD at 1995, involving less than a quarter of Y01-25 practices (Chart 40, p276), and only a third of respondents in the N01-25 sample. It was reasonable to assume that staff development would subsequently be needed to deal effectively with the opportunities and constraints of networked CAD systems as their uptake increased.

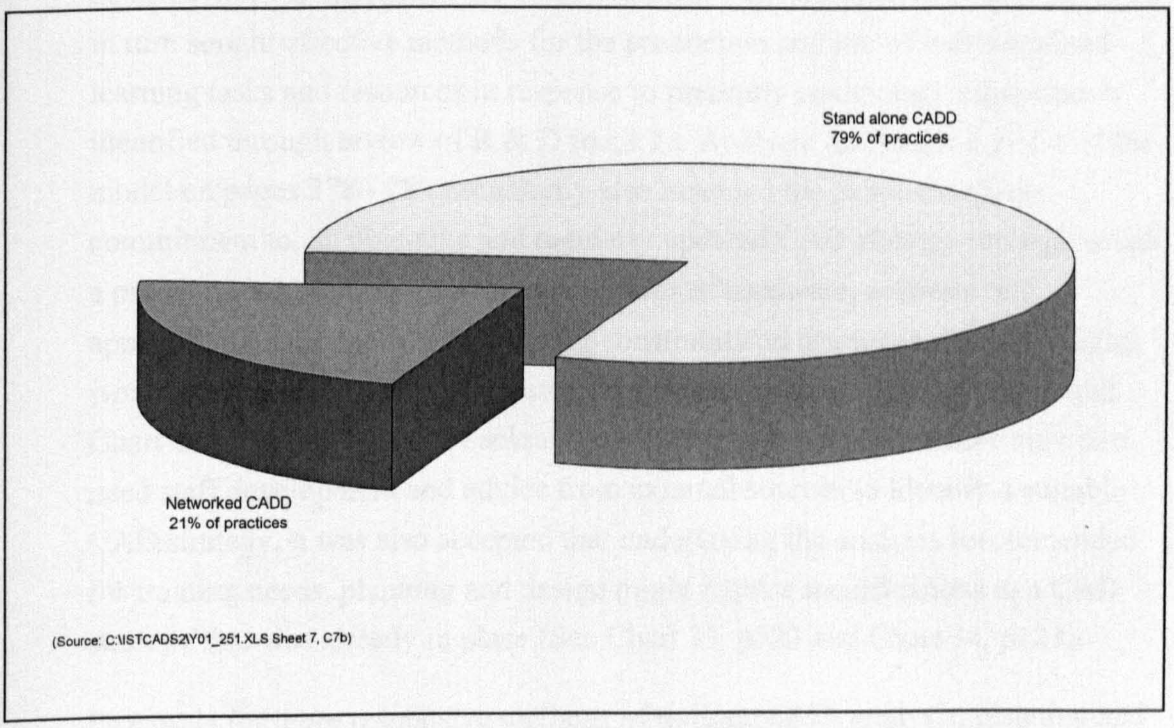


Chart 40 Networked CAD in practices Y01-25 at 1995

Availability of resources in relation to CAD strategies had particular significance for training needs analysis at Stage 1 of the model. This were illustrated by perceptions and provision in the sample for specialised functions. The investigation showed for example a wide variety of proprietary systems in use for measured survey work in preference to purpose-designed software (Charts 38, p145; Chart 33, p123; Chart 23, p91). In fact specialised software for measured survey had both a the low incidence and attracted only minimal use in the overall sample. Different practices with similar needs evidently had conflicting perceptions of functionality. 16% of all respondents considered that the base AutoCAD software gave them specific capabilities for measured building survey work whilst 21% thought that it did not. Use of general purpose CAD software for specialised functions in preference to add-on packages suggested a need for customised application techniques (Chart 23, p91).

Work for R & D focus 2a (p209) to identify effective methods of training needs analysis, planning and design, was undertaken concurrently with initiatives reported on pages 221-271 for extending instructional methods. The various modifications that subsequently resulted for Stages 1.1 - 1.4 of the alternative instructional model necessarily assumed that adequate learning resources would be achievable to implement the enhancements. Consideration of R & D focus 2b in turn sought effective methods for the production and use of individualised learning tasks and resources in response to presently unserviced requirements identified through review of R & D focus 2a. Analysis for Stages 1.1- 1.4 of the model on pages 278 - 283 necessarily also assumed the existence of, or commitment to, an objective and regularly updated CAD strategy through which a practice could select optimal combinations of hardware, software and application methods within prevailing constraints on resources. Such provision would include the CAD-related tasks considered in Chart 27 on page 111 and Chart 28 on page 113. It was acknowledged, however, that a practice may first need staff development and advice from external sources to identify a suitable CAD strategy. It was also accepted that undertaking the analysis recommended for training needs, planning and design might require modifications to a CAD strategy that was already in place (See Chart 33, p123 and Chart 34, p123).

Proposals for more responsive methods of training needs analysis, planning and design in response to the issues identified on pages 274 - 277 are summarised in Fig. 61 on page 278.

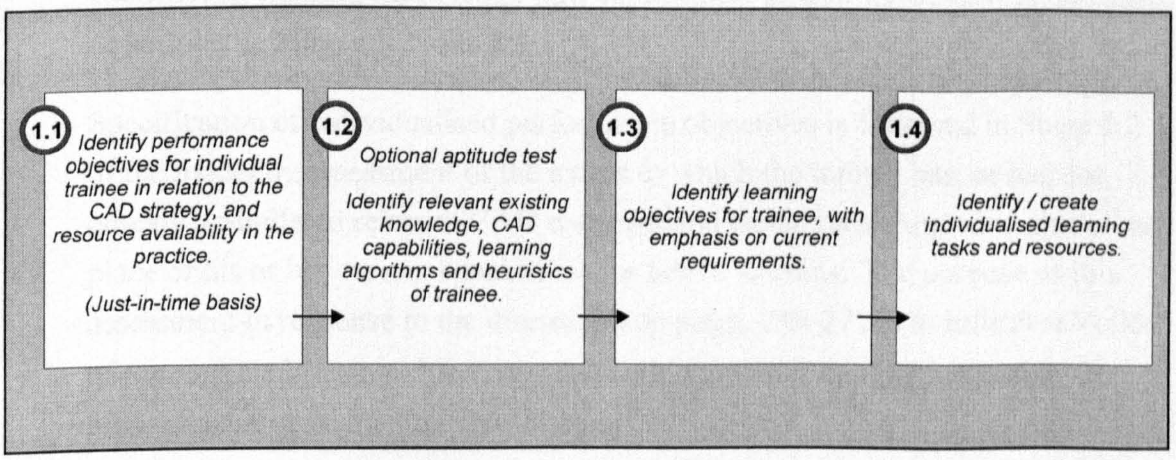


Fig. 61 Revised provision for training needs analysis, planning and design (Stages 1.1 - 1.4 : Model Version 2c)

Individualising performance objectives in Stage 1.1

Revised analysis for identifying performance objectives in Stage 1.1 focused upon future as well as current requirements for the individual trainee. These were assessed in relation to the CAD strategy and availability of resources for its implementation, as distinct from requirements of his or her particular post at the time of analysis. Many respondents to the 1995 survey were still developing overall strategies and particular applications of CAD within them. Specifying performance objectives for the individual trainee, rather than his or her current role in the practice, would allow additional flexibility for modification of that role as the CAD strategy evolved over time. This might come about as a result of the trainee developing CAD capabilities that allowed beneficial changes in his or her post that would not otherwise have been viable. Alternatively expansion of the role may be required by the CAD strategy and business plan of the practice.

The extended scope of Stage 1.1 also acknowledged that development of a trainee's CAD capabilities might enable him or her to contribute productive ideas and capabilities in due course for enhancing the CAD strategy of the practice.

Identifying existing knowledge and capabilities and individualising learning objectives in Stages 1.2 and 1.3

Specification of individualised performance objectives is followed in Stage 1.2 of the model by assessment of the extent to which the trainee has, or has not, already assimilated relevant CAD concepts and techniques. Appraisal also takes place of his or her current capabilities for active learning. The purpose of this assessment in response to the discussion on pages 249-271 is to inform selection of appropriate learning objectives, tasks and resources thereby increasing the effectiveness of instruction and learning.

Whilst permeation of digital methods in social, domestic and economic activity increases the probability of CAD trainees possessing relevant existing knowledge, understanding and practical abilities, the logic of testing in order to capitalise accordingly for instruction, learning and subsequent application in the workplace was unfortunately constrained in practice. Robertson and Downs (1989) advise that the effectiveness of training can be improved by selecting only trainees with an aptitude for responding to instruction and subsequent performance in the workplace. However, small building surveying practices may have little choice of staff to nominate for training. Meanwhile, selection in medium and large practices may be influenced by various other factors. These include the existing commitments of available personnel and resistance of others to the perceived negative consequences of developing CAD skills, primarily the association with technical, rather than professional activity. It was unclear, moreover, what constituted a meaningful test of aptitude for effective use of a CAD system. Observation of skilled users indicates that a number of factors are significant including hand-eye coordination of computer keyboard, pointing device and screen; empathy with digital concepts and techniques; curiosity about new technology and skills; concern for detail; willingness and a capacity for self-monitoring; and a flexible attitude to working practices. Further analysis suggests that those aspects mainly concerned with computer hardware and software are not vital prerequisites for a CAD beginner but can instead be developed subsequently. Furthermore, those able to sustain the practice of building surveying normally display the other attributes listed. Further research was therefore necessary to identify indicators for a reliable aptitude test. It was also necessary to acknowledge that even once such indicators have been identified the utility of corresponding techniques may be compromised by those other factors that influence selection of staff for use of CAD in building surveying practice. In these circumstances aptitude testing of CAD beginners was made an optional provision of Stage 1.2 in the model for those practices with real scope for selecting staff to start using CAD, or in those undertaking training to substantially extend existing capabilities with the technology.

Individualising learning objectives in Stage 1.3

Following clarification of performance objectives for the trainee in Stage 1.1, and relevant existing knowledge and capabilities in Stage 1.2, learning objectives to guide instruction, learning and assessment are identified in Stage 1.3. Where learning objectives are found to be extensive then the model requires that they are dealt with through a corresponding series of learning tasks, starting with those which are most immediately relevant to the trainee's workload. The emphasis for learning objectives in Stage 1.3 of the model was transferred from future requirements to those which are current in expectation of iterating the model to deal with a more extensive set of objectives through a succession of learning tasks.

Planning, design and production of tasks and resources for instruction and learning in Stage 1.4

Revised proposals for Stage 1.4 were a logical progression from developments discussed for Stages 1.1 - 1.3 on pages 278-280. Problems remained, however, with initial specification and design of the content and level of difficulty for a trainee in a learning task during Stages 1.1-1.4 (Fig. 34, p206). These difficulties subsequently transferred to determining whether different attributes were required in use. The instructional model was modified accordingly to facilitate planning and design of learning tasks and associated resources for variations in the availability of staff, and particularly professional staff for training, reinforcement, practice and application of CAD. Allowance was also made for the potential frequency and extent of their subsequent use of CAD. Although other training and development actions were acknowledged as the primary remedy for constraints on availability of staff for instruction, learning, practice, reinforcement and application, instructional methods should respond where practicable to residual constraints on trainees by offering mechanisms readily available for ad hoc remedial and refresher activity. Access was consequently provided to a range of learning methods and resources intended to accommodate variations in these constraints.

Other modifications enabled more effective methods for production and use of individualised learning resources. Responses to the constraints on trainees discussed for Stages 1.1 - 1.3 on pages 131-152 acknowledged the deficiencies, opportunities and implications of experiments with Instructional method 3, the Online Expert-Tutor, Mental Modeller and Procedures Guide reported on pages 210-241.

Central concerns for the design and use of learning tasks and associated resources were individualisation with maximum relevance of content and achievability. A need was accepted to maximise the relevance of content in learning tasks for individual trainees (Model Version 1d) and the achievability of the learning task in Stages 2.1 - 2.4 without compromising attainment of learning objectives. An associated need was recognised for providing a starting point from which production of the target output and allied learning were sustainable. An integral means for such provision was to exploit opportunities for informing instruction and learning for CAD through existing knowledge of, and ability with, other computer systems installed in the practice.

Revisions to Stage 1.4 in the model responded to the tendency for a trainee's understanding of an overall production strategy for target output to develop incrementally during practical involvement with a learning task. Corresponding ad hoc access was needed to a range of learning resources able to accommodate limited availability of staff for instruction, learning, reinforcement, practice and application. These resources should also prove responsive to variations in the existing CAD knowledge and skills of staff and their capabilities for active learning. Due consideration of Instructional method 3 left it the preferred format for paper-based instruction in the alternative model. Potential was also acknowledged, however, for a digital, rule-based mechanism to guide trainees in assimilating relevant concepts and techniques as evident in proposals underlying the On-line Expert-Tutor discussed on pages 221-228. A learning tool of this type might conceivably be interfaced with proprietary on line help resources associated with the subject CAD system. Potential also existed for supplementing proprietary CAD systems with software mechanisms for active and passive use explaining CAD concepts and techniques through individual analogy during learning tasks as had been prototyped in the Mental Modeller (pp228-235). Utility and viability might also be found during a learning task in a computer-based resource customised by the instructional designer to guide the trainee through a hierarchy of appropriate procedures with the CAD system, as in the Procedures Guide reported on pages 235-241. This concept of monitoring and diagnosing deficiencies in a trainee's interaction with the core applications software predated proprietary developments, for example the "Show me" options in Microsoft Office. Phase 3 of R & D also had particular relevance for subsequent research in both confirming opportunities and developing techniques for integrating other proprietary software applications with the core CAD system so that potential instructional methods could be prototyped.

A need was apparent for integrating resource-based and trainee-based learning through specific instruction in methods of active learning. Developing active learning through a range of learning resources superseded requirements for learning tasks to respond to the trainee's particular learning preferences and capabilities. The instructional model was consequently enhanced to develop active learning capabilities more overtly.

Notwithstanding other changes in Stage 1.4 an essential requirement was retained in the alternative model for the trainee to identify an appropriate production strategy for his or her target output from the CAD system. It was anticipated that a general systems methodology could be supplemented with relevant heuristics in order to facilitate this process. Consideration was also given to use of non-critical deadlines to facilitate identification, selection and application of alternative methods by the trainee in order to achieve requirements. The trainee would be obliged either to identify a production strategy within a specified period of time, to seek additional guidance, or to move on in the learning task. Although further review was additionally undertaken of the need for a trainee to identify optimal methods of producing his or her target output it was considered more appropriate to retain specification of an adequate production sequence as the norm.

Revised provision for diagnostic, formative and summative assessment (R & D focus 2c)

Consideration of computer-based resources for instruction and learning of CAD on pages 221-272 suggested that they should logically provide integral mechanisms for assessment and also for remedial action where necessary. Opportunities to achieve this closer integration of instruction, learning and assessment were investigated in prototypes for the Mental Modeller (pp228-235), the Discovery Learning Tutor (pp245-249) and the Active Learning Tutor (pp264-271). In each case provision was made to assess the trainee's performance at regular intervals during the instructional process and to maximise benefits for the trainee from knowledge of results, as recommended by Patrick (1993), and from diagnostic advice to remedy deficiencies.

Expressed need of practices for improved productivity from their CAD resources, in the context of progressive development of CAD software and corresponding application methods, indicated a sustained requirement to enhance the CAD knowledge and skills of staff in the workplace to service authentic local methods. Given the emphasis placed by practices upon improved productivity (Chart 8, p66), and the extent to which it had not achieved, a particular need existed for the instructional model to assess and remedy defects in application of key software functions to efficiently achieve specified results. Improving productivity through staff development in any particular practice was likely to be achievable by two routes. In the first case efficiency could be improved by ensuring that all CAD users in the practice were able to operate within agreed norms. On this basis 2-D drafting applications, as the primary CAD application type (Chart 34), offered greatest scope for accumulating benefits through repetition of marginal improvements in procedures. Although availability of in-house expertise to support training for achieving these gains was likely to be greater than for other CAD applications, effective computer-based resources to support such developments would be beneficial. In the second case productivity gains could be achieved by active learning and collaboration to identify and exploit opportunities for improving upon existing production strategies and to identify more effective alternatives. Development of assessment mechanisms for these capabilities was, however, dependent upon classification of methods for active learning in Context 3 (pp261-263).

Formative assessment and diagnosis of performance deficiencies for this purpose should include time spent by the trainee in preparation for applying particular procedures and also the period required for their actual execution. Assessment should also be made of the acceptability of output achieved by the trainee from the CAD system. A logical implication of more effectively individualising instruction and learning in Stages 1 and 2 of the model was to use local workplace norms as performance standards when assessing application of CAD functions. Opportunities existed for exploiting the digital medium by structured recording of assessment results in a digital database of performance history that would inform the design of subsequent learning tasks and specification of associated computer-based assessment. Consideration should also be given to the benefits, opportunities and constraints of reusing those mechanisms provided for formative assessment in Stages 2.1-2.4 later in Stage 3 of the instructional model to undertake summative assessment. It was apparent, however, that the primary assessment criteria in Stage 3 would focus on the trainee's ability to produce appropriate target output for the specified context and purposes within an acceptable period of time. Summative assessment of this capability was likely to subsume testing for effective use of individual software procedures.

Applications Assessor

Rationale

Patrick (1993) makes a convincing case that knowledge of results which include accurate diagnosis of performance difficulties and identify potential for improvement, provides trainees with a powerful tool for learning. Dryden and Vos (1994) make an equally compelling case for wider application in education of a sports coaching ethos and instructional methods in which the instructor and trainee regard timely and accurate diagnosis of errors as a positive route to more effective techniques and performance. By contrast, conventional methods of in-service training for CAD which had so far been identified in the research programme demonstrated few instances of assessment capitalising upon such opportunities. The Applications Assessor was conceived as a computer-based resource specifically for developing productivity. Consideration was initially given to real-time verbatim recording of the trainee's use of the CAD system to replay for assessment by the instructor. The Applications Assessor was intended to provide a computer-based mechanism for development and associated formative and summative assessment of fluent selection, sequencing and performance of relevant CAD procedures.

Components and methods

A schematic of essential processes and software components for the prototype Applications Assessor is shown in Fig. 62 on page 286. DDE instructions from a customised AutoCAD menu activated a ToolBook floating window through which the Applications Assessor communicated with the trainee. OpenScript routines in the ToolBook application interacted through the DDE channel and text files with AutoLISP procedures to control and inspect entities in the AutoCAD graphics window and the underlying CAD environment.

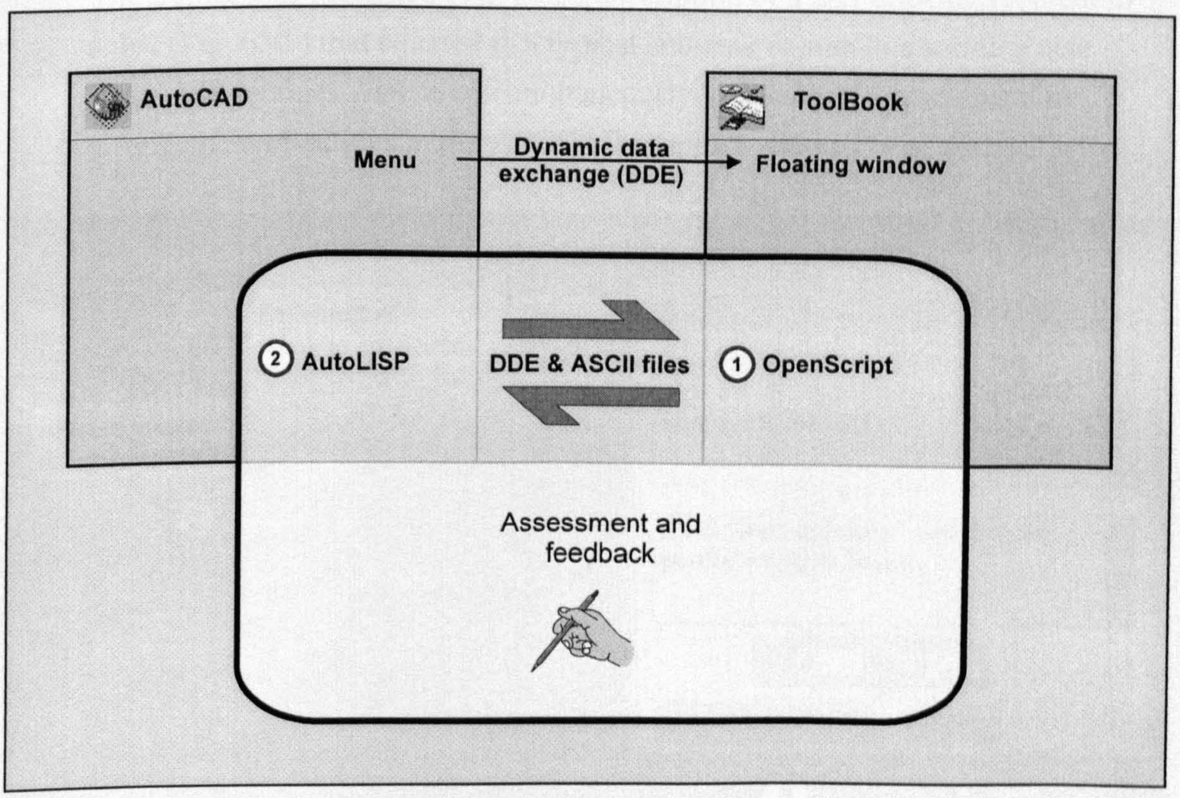


Fig. 62 Software components in the prototype Applications Assessor

The trainee was presented with a text description of a 2-D drawing problem to solve (Fig. 63①) that equated to a typical sub-task or step in a learning task. AutoLISP routines were used simultaneously to construct a corresponding arrangement of entities in the AutoCAD graphics window (Fig. 63②).

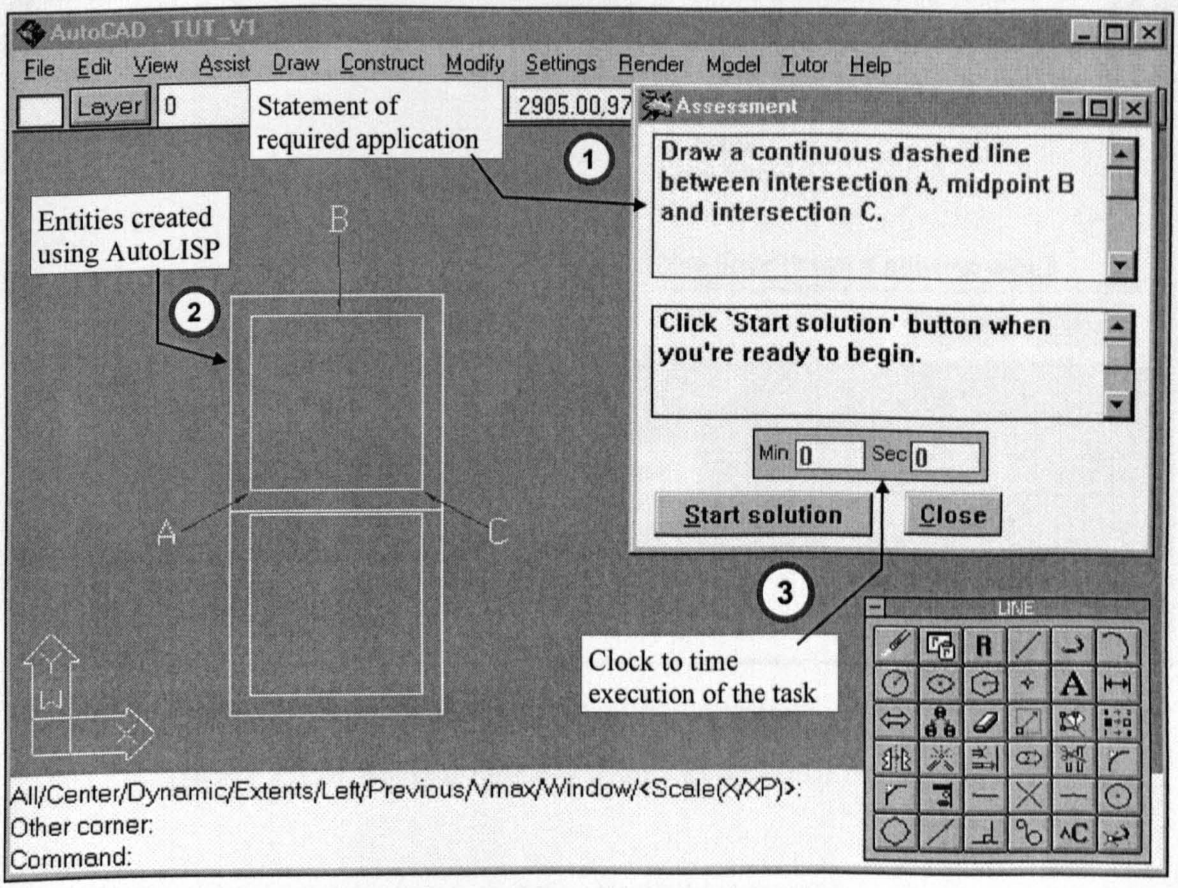


Fig. 63 Problem to solve in the Applications Assessor

(Source: c:\icad_rep\report1.tbk)

The trainee was then able to use inquiry commands, display controls and proprietary on line help in the CAD system, to investigate the requirement before signalling the start of a his or her application attempt. The system responded by activating a timer with on-screen read out (Fig. 63③). The trainee could request assessment of the application from the software at any time. Feedback from analysis by AutoLISP routines of the trainee's use of the CAD software included an evaluation of the time taken, and remedial guidance on errors of omission or commission (Fig. 64①, p288). Where appropriate, discrepancies were identified visually in the graphics window, as shown in Fig. 64②, p288.

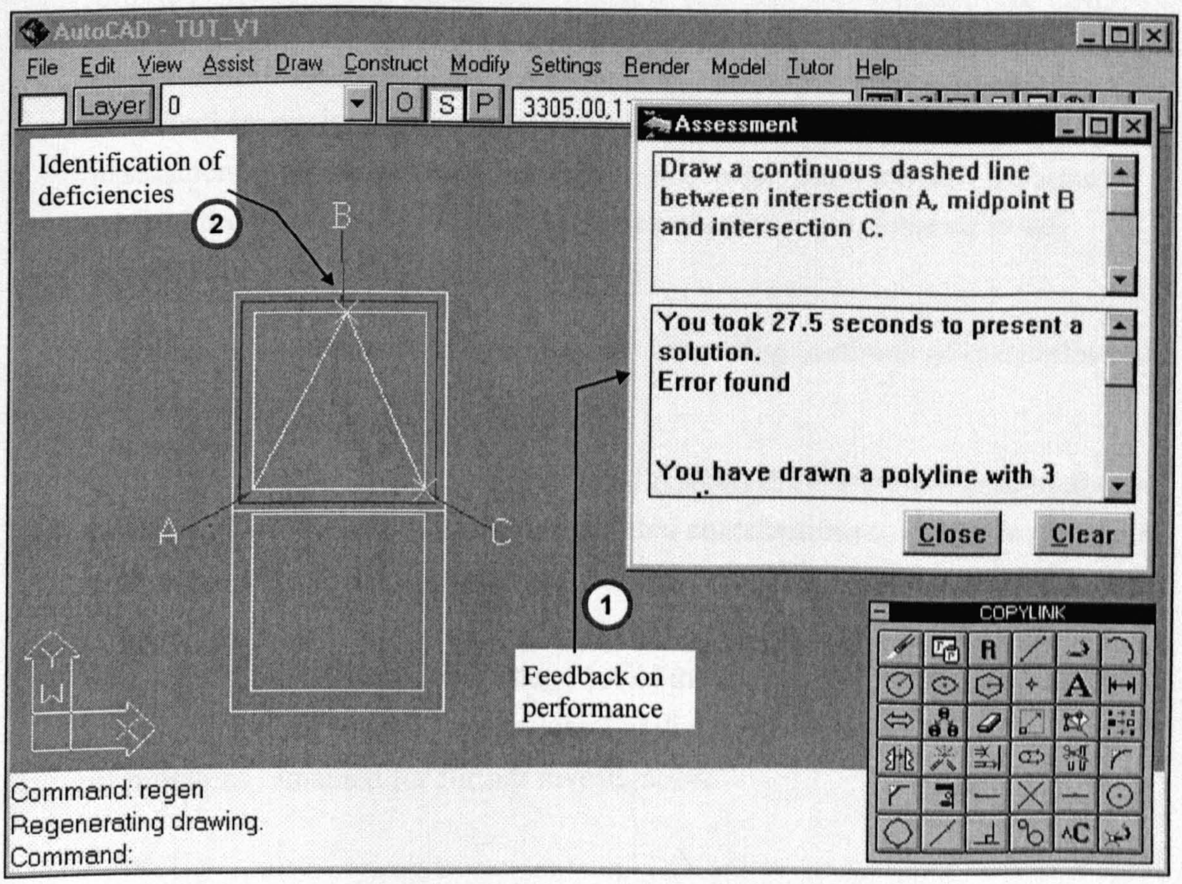


Fig. 64 Remedial feedback in the Applications Assessor

(Source: c:\icad_rep\report1.tbk; c:\acadwin\support\assess1.lsp)

Performance of the prototyped Applications Assessor

Although the prototyped mechanism for the Applications Assessor was technically demanding and time consuming to develop and maintain, it demonstrated considerable potential for viable computer-based formative and summative assessment in the model. In common, however, with the Mental Modeller mechanism, described on pages 228-235, a more robust prototype was needed of the Applications Assessor for classroom testing with instructors and trainees. Further investigation was also needed of mechanisms by which proficient users of CAD in a practice could calibrate the Applications Assessor with preferred procedures and performance standards, followed by their regular updating as applications developed locally. Such constraints may have contributed to reasons why neither Autodesk's Inside Track (1996) or its Learning Assistance (1997) computer-based training systems subsequently provided for computer-based assessment of practical application of the CAD system.

Results from analysing opportunities and requirements for computer-based assessment mechanisms, and developing and testing the prototype, informed revised proposals for assessment in Version 4a *of the instructional* model synthesised in Section 3.14, (pp332-381).

Constraints and potential solutions for extending methods of instruction and learning

R & D Phase 3 found that for a variety of reasons the computer-based methods prototyped were likely to make only limited contributions to effective instruction and learning in the alternative model. Notwithstanding progress with achieving effective methods for production and use of individualised learning tasks and resources (R & D focus 2b) in Stage 1.4 of the model, and in the context of developments for instruction and learning discussed on pages 210-271, a range of problems remained for further investigation.

Cost

The first problem concerned the resource implications of the required processes and mechanisms. Proposed analysis, planning and design depended upon timely and appropriately detailed data collation and processing for particular practices and trainees. The subsequent costs of production and delivery of individualised learning tasks and their associated resources would moreover, be substantial. The costs of providing and maintaining the Mental Modeller software alone would for example be considerable. These requirements raised the possibility of collating data by computer-based means, possibly via the World Wide Web, and their subsequent processing using software tools for knowledge engineering.

Technical requirements of developing computer-based resources

A number of technical difficulties affected development of computer-based resources for instruction and learning. The requirement for a programmable CAD system through which to integrate the instructional mechanisms considered on pages 221-268 was problematic since the 1995 survey of practices had shown that not all respondents used CAD software with such capabilities. Where they did exist, as in AutoCAD, a high degree of flexibility for constructing end user applications proved more limited for generating integral instructional resources.

Gaining access to internal data through which to monitor the trainee's interaction with the CAD software system and purpose-designed instructional components was particularly problematic. Although the action research programme necessarily investigated alternative instructional methods through small-scale practical experiment the extensive programming and customisation capabilities that were available placed heavy technical demands on software development. These constraints of software tools and techniques contributed significantly to some experimental mechanisms, for example the prototype Active Learning Tutor, being insufficiently robust to test with instructors and trainees in the classroom. For similar reasons they also became too technically exacting to refine and enhance within the resource constraints of the research programme.

Prototyping of the rule-based On-line Expert-Tutor was limited by problems defining a rule set for interfacing with a large and complex software system. Constraints on defining the knowledge base were intensified by a presumption in the available knowledge engineering software for mutually exclusive attribute values, and for predominantly text-based communication with the user. Whilst these obstacles were unlikely to be overcome for specific instructional and learning resources, potential was indicated for using rule-based decision-making mechanisms for strategic guidance elsewhere in the model.

Limitations of computer-based methods

By the end of R & D Phase 3 a number of pedagogic problems were also evident with the computer-based prototypes constructed for instructional resources to service the alternative model. Inadequate mechanism existed in the Mental Modeller for achieving timely transition from passive to active learning. Potential was consequently apparent for reinforcing sub-optimal methods of learning. A lack of monitoring capabilities in the replay software used for the Procedures Guide prevented review and remedial advice on the trainee's performance of relevant functions in the CAD system. Providing a microcosm of the proprietary CAD software in an Active Learning Tutor running alongside the actual CAD software was potentially disruptive and confusing for the trainee.

Many of the computer-based instructional tools prototyped depended upon an extensively customisable CAD system, as observed previously. The extent to which assessment and remedial feedback on the trainee's use of particular CAD functions could be automated was, for example, dependent upon this capability. Since in practice the availability and sophistication of relevant programming facilities varied considerably between proprietary CAD systems opportunities for integrating digital learning resources would vary accordingly. As the computer-based instructional tools prototyped would not be universally applicable the need to substitute manual and interpersonal alternatives would also vary between CAD systems.

There was mounting evidence, therefore, from results obtained through prototyping that computer-based mechanisms for instruction and learning may be *inherently limited* by comparison to appropriate and well executed manual and interpersonal methods. It was presumed at this stage, however, that *substantial* elements of the concepts underlying computer-based instructional resources prototyped in R & D Phase 3 (pp210-271) could be successfully implemented given appropriate technical resources. In some cases suitable technology already existed but was simply unavailable. The expectation in other cases was that computer-based mechanisms would become viable with future technical developments.

Limited understanding of active learning methods

An important factor in further progress with Stages 1.1 - 1.4 of the instructional model was improved understanding of the self-directed processes undertaken by an effective CAD user when progress with an application is restricted by deficient knowledge, understanding or practical ability. To this end further testing was needed to refine or replace the algorithms and heuristics identified for active learning in Contexts 1-3 (pp254-264). Similarly further research and development was required to devise corresponding instructional methods for achieving appropriate capabilities in trainees. Concepts underlying the prototyped Discovery Learning Tutor had been too prescriptive whilst the methods attempted were too mechanistic. An improved conceptual basis underlay the Active Learning Tutor but significant technical difficulties constrained development of the prototype, as discussed above.

Hybrid implementation methods

R & D Phase 3 indicated a requirement for hybrid methods in response to the various constraints of manual, interpersonal, paper-based and computer-based resources for instruction and learning to apply CAD systems discussed on pages 153-273. Such difficulties originated partly from inherent limitations of the various methods and partly from underdeveloped concepts or implementation mechanisms. They also derived from limitations of manpower, time and equipment available to a particular instructional designer in any given case. The most obvious example of interaction between these different constraints in R & D Phase 3 was the computer-based Active Learning Tutor (pp264-271). Such results indicated a need for further research and development of optimal mixes of methods for achieving effective training in CAD, and ways of implementing an optimal mix of methods for a specific workplace and trainee. A successful mix was likely to require ad hoc intervention by the instructor and trainee to moderate inherent and case specific deficiencies of resources available for instruction and learning.

It had initially been assumed that computer-based resources should and could be able to fulfil their proposed functions in the model largely independently of other instructional methods available to the trainee. It was clear by the end of R & D Phase 3, however, that this assumption placed considerably higher demands upon software solutions than could be accommodated by available technology for the foreseeable future.

Assessment

A number of problems either remained or had become apparent by the end of research and development Phase 3 with assessment of the trainee's performance within an individualised learning task. In particular difficulties were evident for:

- Diagnostic assessment in Stage 6 (Fig. 34, p206) of the trainee's capability to identify a production strategy.
- Adequacy of the production methods identified for Stage 6 of the model.
- Assessment of whether more could and should be learnt from a task, or if the trainee could beneficially proceed to summative assessment.