

Accelerating learning via virtual site visits

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ABSTRACT | Web-based ‘virtual site visits’ have added a new dimension to the teaching-learning environment of civil and construction engineering undergraduates in Hong Kong. Virtual visits, to both landmark and typical construction projects, overcome many obstacles, such as in moving large classes to the right places at the right times. They also enable convenient re-visits and multimedia enhancements for comprehensive appreciation of all relevant aspects. Such benefits have been demonstrably derived through CIVCAL – a computer aided teaching-learning package developed by a four-university multi-disciplinary team in Hong Kong. This paper provides examples of the multimedia-enhanced resources that are now available for supplementing teaching-learning through CIVCAL. The construction ‘work study’ module is described as an example of potential extrapolation to continuing education and better practice. This would also respond to recent industry pressures for enhanced value and productivity via ‘lean construction’ initiatives. Overall, the CIVCAL package also provides an example of another dimension in ‘knowledge’ capture and dissemination towards continuous improvement and organisational learning.

KEYWORDS | construction, CIVCAL, Hong Kong, multimedia, virtual site visit, web-based

1 Introduction

Over the years, Hong Kong has hosted a series of innovative and/or special, if not pioneering, construction methods in land reclamation, slope protection/ landslip prevention [1, 2], tunnel, bridge and building construction [3]. First-hand exposure to these innovations should be valuable in enhancing both construction education and organisational learning. However, arranging ‘real’ site visits for large groups of undergraduates is not easy, as is also seen in many other countries e.g. Australia [4]. Site safety

concerns, large class sizes, tight time-tables, busy site management and distant sites have drastically reduced such useful opportunities for a close-up appreciation of innovative and interesting construction processes.

Furthermore, ‘learners’ could not be transported ‘in real time’ to completed landmark projects which had employed much talked/ written about ‘ground-breaking’ construction processes. Virtual site visits via the web were seen as the next best thing to fill these growing gaps. A multi-pronged joint project to address these needs was launched in late 1997 by

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four Hong Kong Universities, led by the University of Hong Kong. The resulting CIVCAL (Civil Engineering Computer Aided Learning) package, uses multimedia tools to enhance the visualisation of a wealth of material collected from a wide range of recent and ongoing construction activities. This paper includes some highlights of the various approaches to capturing, processing and presenting such material, that target the computer aided teaching-learning of civil engineering and building construction undergraduates. Examples are presented from an extensive multimedia database that was developed in the University of Hong Kong domain of the package. This database includes photographic narratives, construction details and programmes, video clips and animations, as well as navigation and teaching tools developed specifically for CIVCAL. Highlights from other university domains are also included.

Added value benefits of CIVCAL are discussed in terms of its usefulness to industry. This is in response to perceived needs, for example in: (a) providing computer assisted learning support to various construction personnel [5]; and (b) accelerating organisational learning via multimedia enhanced knowledge capture, dissemination and enhancement [6].

2 CIVCAL development

The CIVCAL project was primarily funded by a competitively won Teaching Development Grant from the Hong Kong University Grants Committee and carried out by an inter-institutional and multi-disciplinary team. The team brought together academics from relevant Departments in the Hong Kong University of Science and Technology, the Hong Kong Polytechnic University and the City University of Hong Kong – led in this project by the Department of Civil Engineering of The University of Hong Kong; and supported by multimedia/teaching development centres/ units in the respective Universities. The coverage encompassed

a wide range of disciplines in civil engineering, building and construction, including geotechnical, structural, environmental, water, trans- portation and construction engineering.

The CIVCAL package was essentially developed to supplement classroom teaching by ‘bringing sites to the students’, since it was increasingly difficult to take students to construction sites. Apart from such difficulties, CIVCAL also captures and enables ‘revisits’ to special scenes from completed projects that used innovative construction methods. It also mobilises multimedia tools in a web-based teaching-learning package to illustrate theory and demonstrate useful applications in chosen topics, such as the ‘water supply in Hong Kong’ or ‘construction work study’.

The above aims, general coverage, main thrusts, broad contents and principal common formats were jointly agreed by the four Universities at the outset. It was also agreed to independently develop sets of modules within separate University ‘domains’. This was to cater for different priorities such as (a) a focus on supplementing specific in-house courses (as targeted by the City University), or (b) extensive coverage of a megaproject to convey a range of information in a particular discipline, as in the Hong Kong Strategic Sewage Disposal Scheme focused upon by the University of Science and Technology; (c) development of project-specific site visit modules (e.g. on the Three Gorges Dam project), supplemented by topic-specific modules (e.g. on the Geology of Hong Kong), as developed by The University of Hong Kong, and also by the Hong Kong Polytechnic University. Consistency was maintained and synergies were derived by regular inter-University reviews, as well as through CIVCAL project steering committee interactions. Many new modules were conceived and developed during the course of the project.

The integrative framework, formats and common search & access facilities were developed by the

University of Hong Kong lead sub-team. However, in recognition of the different priorities and desired presentation formats, the opening page of CIVCAL is designed for separate access to each university 'domain' through four distinct University-specific gateways. The main CIVCAL opening page can be accessed through the url address <http://civcal.media.hku.hk> on the internet.

3 Screen design and navigation

CIVCAL was primarily intended for facilitating both teaching and outside-class learning. The primary CIVCAL users were expected to be teachers who would transport their students to 'sites' on the classroom screen and students who would visit and re-visit topics and construction sites at their own convenience. Other audiences (such as Continuing Professional Development trainers and trainees, researchers and construction personnel) were also considered, but the teaching-learning requirement was considered to be paramount. A focus on classroom teaching i.e. to increase presentation efficiency and communication effectiveness, led to a series of formatting guidelines, such as to:

- develop the package in HTML and access it using a browser, although CD-ROMs may also be provided if convenient
- set the screen size to 800x600 pixels (effectively 750x580 with a web browser)
- optimise the site for Internet Explorer 4+ and Netscape 4+ with a minimum number of standard plugins (eg. Quicktime, Flash, Whip)
- facilitate the main navigation through thumbnail images linked to high quality large images in JPEG format.

Efficient navigation was recognised as critical from the outset. With an initial target of at least 5,000 images (that was soon surpassed), the project team was acutely aware of the potential problems that users may encounter in (a) finding the appropriate material/image and (b) keeping track of their position. The

navigation system thus became an integral part of the screen design. A number of navigation schemes were considered, including a site-map "tree" and pull-down menus/sub-menus. The team eventually decided on the metaphor of a card index as the top-level organising scheme. Based on this:

- the top-level organising principle of the site was initially decided to be 'projects', as shown in Fig. 1. However, 'topics' were also used as a parallel basis in subsequent developments
- projects were then divided into discrete stages/processes/ packages e.g. as in Fig. 2
- each stage/ process/ package was subdivided into items/ sub-processes e.g. as in Fig. 3
- an illustration of each sub-process can be accessed via a series of thumbnail images e.g. as in Fig. 3, that are linked either to corresponding larger images with accompanying text e.g. as in Fig. 4; or to animated illustrations e.g. as in the opening frame of an animated bridge girder launching process, as indicated in Fig. 5
- text was minimised and PDF documents were used for Tables, Diagrams and Graphs where useful, or video clips or animations are used as mentioned above

For the frequently repeated content screens (e.g. Figs. 2 and 3), a standardised screen design was adopted based on four HTML frames:

- **Top left:** module identification – links back to the top page of the module
- **Top to Top right:** Navigation tabs linking to stages/ components/ packages of the project. This also contains a link back to the HKU top level menu
- **Left column:** contains sub-menus to procedures within stages/ components/ packages, plus a set of standardised icons leading to 'Back one level', Search, Home and Contents facilities
- **Centre to Bottom right:** main page containing all relevant information. This page is maximised at the lowest level in order to provide as much space as possible for images and text.

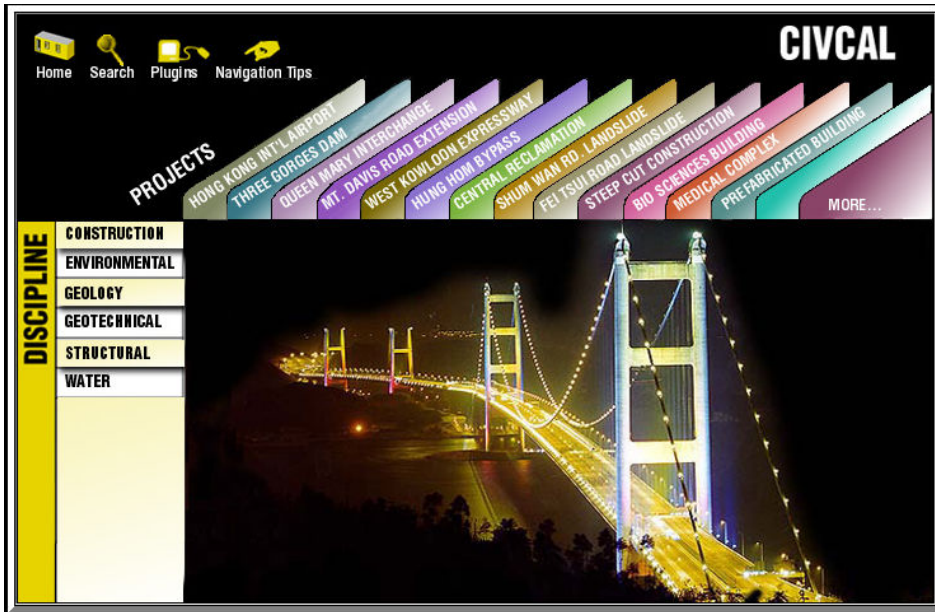


Figure 1. Opening page in the 'HKU domain' with top row tabs leading to 'Projects'

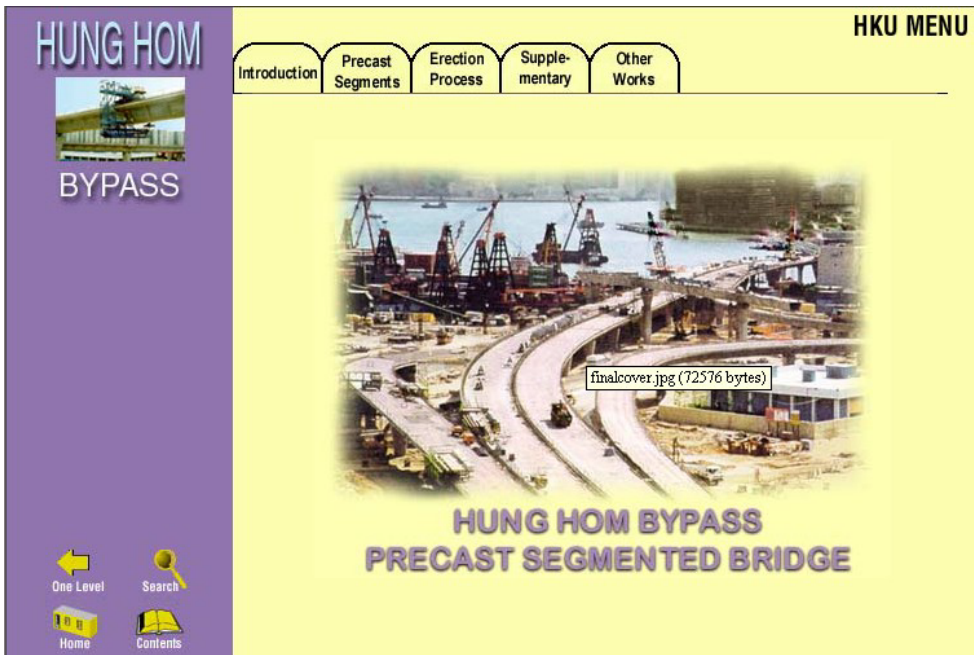


Figure 2. Top level of a 'Project' page with Links to work packages/ processes



Figure 3. Thumbnail Images illustrating a 'Process' within a Project

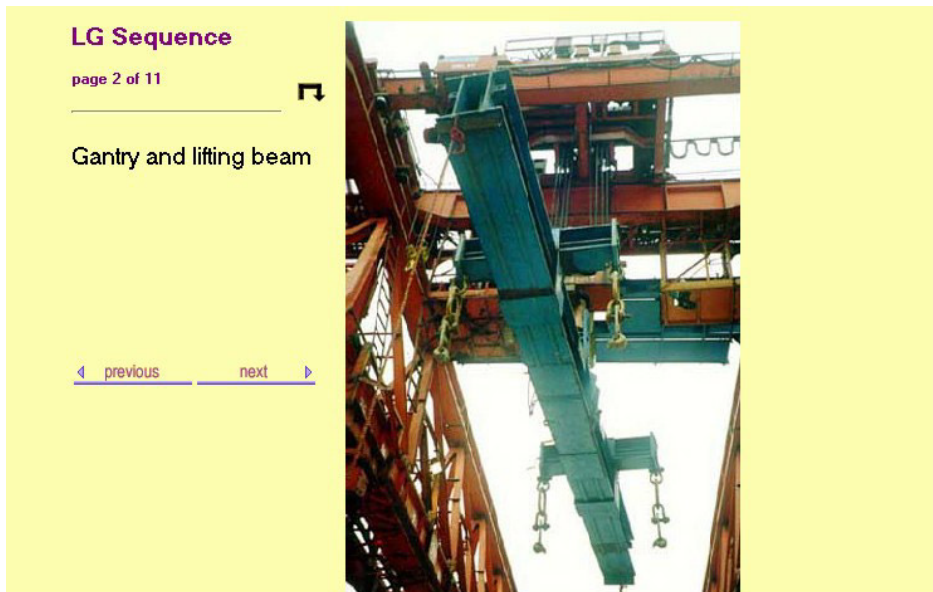


Figure 4. Full Image (blown-up from one of the Thumbnail Images in Figure 3)

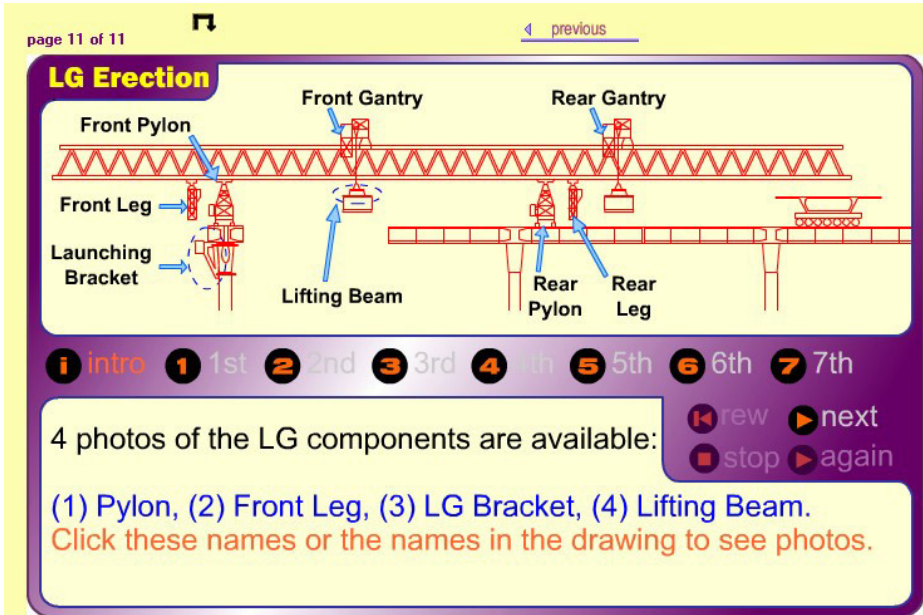


Figure 5. Initial (start-up) Frame of an Animation illustrating a sub-process within a Project (as accessed from one of the 'Thumbnails' in Figure 3)

The above basic design principles and guidelines were essentially followed with some minor modifications during the project. For example, it was soon evident that the "Project" classification was not suitable for every module (e.g. 'Construction Work Study' and 'Geology of Hong Kong' were better described as "Topics"). User feedback also indicated that there was a need for additional means of accessing and using the material. The incorporation of modules from the other three institutions also necessitated some modifications to the basic structure that had been originally planned. For example:

- (1) a key-word search was added to enable navigation across the whole CIVCAL site; while
- (2) in the University of Hong Kong (HKU) domain, [i] tabs on the top menu were reclassified into two sections: Projects and Topics (only the projects are shown in Fig. 1); and [ii] a "Discipline" menu was added to enable navigation across projects according to specific disciplinary interests, such as Construction, Environmental or Geotechnical

Engineering. This necessitated a new sub-menu structure to reflect this matrix approach (as in Fig. 1).

The overall design and structure of the HKU domain in CIVCAL was thereby systematised to provide a simple and logical means of dual navigation. A similar structure and design was adopted by one of the other Universities. The other two Universities geared their specific domain designs and structures to suit their own special objectives and to optimise access to their particular content materials.

4 Highlights of the 'HKU domain'

The matrix structure of The University of Hong Kong (HKU) opening pages permits access either: (1) through one of 13 projects as listed across the top row of the first page (as in Figure 1), or one of 12 topics as listed across the top row of the second page (e.g. 'Water Supply in Hong Kong'); or (2) through one

of the six disciplines (ranging from ‘Construction’ to ‘Water’) in the first column to the left of either page (as also seen in Figure 1).

The ‘Navigation Tips’ icon at the top of either opening page provides guidance on accessing information through such (1) project-based or (2) discipline-based searches, or (3) a keyword search covering both projects and disciplines in the HKU domain. In addition, HKU developed (4) a cross-university ‘index’ facility that enables searches across all four University domains, based on common basic (higher-level) keywords/sub-topics.

As seen in Figure 1, the ‘projects’ include the ongoing ‘Three Gorges Dam’ megaproject in Mainland China, and range from the famous Hong Kong Airport to ‘repair projects’ on infamous landslides, and also from major highway projects to traditional high rise and prefabricated building construction. ‘Topics’ on the other hand range from ‘geology’, ‘transportation’ and ‘waste water treatment’ in a Hong Kong context, to the ‘soil nailing’ technique and ‘construction work study’, as shown in Table 1.

Plug-in tools such as QuickTime movies, Shockwave (Flash), Acrobat Reader and Whip Autocad drawing viewer are mobilised to enhance various presentations. For example, a QuickTime panorama of the ‘BioSciences Building’ site provides a useful overview,

while ‘Flash’ animations help visualise construction techniques and sequences in the ‘Three Gorges Dam’, ‘Hung Hom Bypass’ and the ‘Steep Cut Construction’ projects. Programmes, charts and drawings are viewed more conveniently through the Acrobat Reader and Whip Autocad Drawing viewer, while Video clips effectively track and demonstrate construction activities in the ‘Construction Work Study’ module. This is described in a subsequent section.

5 Main thrusts of the city U, HKPoly U and HKUST domains

5.1 CityU (City University of Hong Kong)

City University’s contribution to the CIVCAL project was consistent with the Virtual Site Visit metaphor that integrates with the overall Web site. It focuses on Housing through a ‘Virtual Construction Site’ of three tours (time-based presentations), three representative models of Low, Medium and High Rise housing and two ‘Offices’ for Production and Design. The construction context is exemplified by highlighting some of the major building construction projects in Hong Kong.

Multimedia consisting of photographs, diagrams, animation, video segments, audio commentary and explanations, time-lapse digital images and instructional text, is used throughout the site for

Table 1. High-level ‘Topics’* in the HKU domain – as accessible from the 2nd opening page

| Topics* included in the HKU domain of CIVCAL | |
|----------------------------------------------|-----------------------------|
| Geology of Hong Kong | Flood Control |
| Soil Erosion | Waste Water Treatment |
| Soil Nailing | Solid Waste |
| Rubber Dam | Engineering Materials |
| Water Supply in Hong Kong | Construction ‘Work Study’ |
| Urban Drainage Systems | Transportation in Hong Kong |

* i.e. excluding the 13 ‘Projects’ that are accessible from the first opening page

delivering education content, creating interest and promoting multi-sensory experiences.

The examples of construction techniques were carefully selected to convey the underlying content which is further 'consolidated' through the building construction details and the design and production information provided in the virtual offices. Additional features that take advantage of the attributes of web technology include such aspects as:

- ability to down-load CAD drawings of a recent CityU building
- suitable academic links to reference sites
- on-line publication of outstanding construction sites in Hong Kong
- search and locate facilities
- interesting functional interface for easy navigation
- feedback mechanism for comments on the site's effectiveness.

5.2 HKPolyU (Hong Kong Polytechnic University)

Although space constraints preclude detailed examples of the domains of all universities, it may be noted that the HKPolyU domain has a similar structure to the HKU domain. It incorporates site visits to projects such as the HKPolyU Main Building and the Pak Sek Kok Reclamation. The former follows the whole process of 'reconstruction' of this building and includes five modules on building demolition, piling, foundation construction, tower crane erection and reinforced concrete superstructure. The latter introduces the basic design considerations and the typical construction procedures in reclamation.

It also incorporates 'topics' as in the HKU domain, e.g. on 'Computer-Aided Learning of Structural Behaviour' which helps students to understand the basic structural behaviour of trusses, beams and frames through games, paradoxes, and exercises.

5.3 HKUST (Hong Kong University of Science & Technology)

HKUST focused on extracting examples for teaching-learning from an important mega project that had been designed to solve the major sewage disposal predicament in Hong Kong – that had over the years led to the 'opposite' of the Chinese meaning of Hong Kong (translated as 'fragrant harbour'). It has proved possible to cover a spectrum of civil engineering aspects, ranging from geotechnical and hydraulic engineering to waste water treatment in this domain.

Extensive material from the SSDS (Strategic Sewage Disposal Scheme) project has been directly integrated into and effectively used in undergraduate courses covering topics in fluid mechanics, hydraulics, environmental hydraulics and wastewater disposal. In the case of topics being covered in the environmental hydraulics and wastewater disposal areas, the SSDS site has created the basis for developing a problem centred learning approach, which has been well received by students. In all cases the material provided from the CIVCAL sites has provided valuable insights for students into the engineering applications of the material being taught and hence additional motivation to learn the material presented to them.

6 Multimedia-enhanced 'Construction Work Study'

6.1 Background

The shortcomings in teaching 'Work Study' principles, techniques and explaining examples in a traditional classroom mode led the author to recognise the usefulness of multimedia tools and virtual site visits in designing a more effective presentation. This makes it much easier to introduce students to the benefits of evaluating different methods (and indeed to the availability of multiple choices) in selecting appropriate construction methods. The 'Construction Work Study' module is thus intended to supplement

the teaching-learning of techniques that are of particular value to the construction industry – in this case aimed at an enhanced appreciation of construction productivity evaluations and improvements.

6.2 Re-visiting 'Work Study' to enhance Construction Performance

Step gains in construction industry performance levels have recently been demanded worldwide [7], for example: (1) in 'Rethinking Construction' – i.e. in the 1998 'Egan Report' in the UK, (2) in 'Re-inventing Construction' – i.e. in the 1999 'Construction 21' recommendations in Singapore, (3) in the 1999 'Building and Construction Industries Action Agenda' in Australia and (4) in the 'Construct for Excellence' Report of the Construction Industry Review Committee in Hong Kong in 2001. The Hong Kong construction industry is being primed to address the root causes of performance problems by a high-powered Provisional Construction Industry Co-ordination Board. One of the five Working Groups that was set up to move this forward is specifically working on 'Cost and Performance Indicators' – since February 2002. Productivity levels are important performance aspects that need evaluation.

Dramatically enhanced productivity levels require deeper understandings of construction processes and a critical search for better alternatives at each stage of each process. Recently developed 'lean Construction' approaches focus on eliminating the 'fat' by minimising the non-value-adding activities (such as resource 'flows') in construction processes and optimising the efficiencies of value-adding activities ('conversions') in construction processes [8]. These approaches draw on reported successes of 'lean production' which led to dramatically reduced resource inputs in some manufacturing scenarios, as highlighted in the above-mentioned 1998 Egan Report in the UK.

In this context, it is evident that the basic principles and 'less modern' techniques of 'Work Study' could

themselves be profitably re-visited and 'recycled' to minimise non-value-adding flows in construction processes and work sites. Work Study could help to enhance efficiencies through its two-pronged strategies i.e. (1) by analysing and improving construction methods through 'Method Study' and (2) by evaluating and improving resource performance levels through 'Work Measurement' [9]. Specific Work Study techniques have been suitably adapted to construction scenarios. For example, tools such as 'flow diagrams', 'flow charts' and 'multiple activity charts' have been developed for 'Method Study'; while 'time study' and 'activity sampling' tools have been refined for 'Work Measurement' in construction scenarios. These tools assist for example, in identifying bottlenecks, reducing double-handling, and in evaluating & improving resource utilisation levels. The irony that such powerful and simple performance-enhancing tools are rarely applied in under-performing industries, may be traced for example, to: (a) the sustained pressures on construction projects and personnel that discourage time spent on even medium-term 'self-improvement' or (b) limited knowledge of the tools themselves.

6.3 Use and Usefulness of the 'Construction Work Study' Module

The CIVCAL module on 'construction work study' is designed to facilitate more efficient teaching-learning of what may otherwise appear to be tedious techniques, and to demonstrate the productivity shortfalls that may be addressed. This module provides an introduction to the principles and practices of Work Study and mobilises multimedia tools to demonstrate productivity measurements and alternative construction methods, with a focus on concreting operations. Video clips of concreting cycles in the 'time study' component help to illustrate the development of 'multiple activity charts'. These highlight idling resources e.g. in multi-resourced concreting activities, and thereby invite consideration of alternative resource mixes or methods. Illustrations from different parts of this module are shown in Figs. 6, 7 and 8.

Extracts from research-based results from case-studies are also included for parallel reference, to highlight typical utilisation levels of resources such as tower cranes, truck mixers and different types (trades) of workers deployed on concreting operations. Spotlighting the present utilisation levels may hopefully inspire action plans for improvement. These comparisons could therefore reach beyond teaching-learning, to provide a basis for benchmarking exercises, or as part of a training and continuing professional development package at a wider industry level.

7 Comparisons, extrapolations and conclusions

7.1 Comparisons

The need for virtual site visits which drove the initial CIVCAL initiative, unsurprisingly also led to the launch of somewhat similar initiatives in other countries in parallel. For example, in Australia, Kajewski [4] described the development of a computer

package at the Queensland University of Technology, that enabled virtual tours of construction sites, at that time incorporating two case-studies. Virtual reality walkthroughs are also facilitated in a '4D' computer framework developed at the University of Melbourne. This facilitates simulated site visits at different time in the project (the fourth dimension) via an internet deliverable Oracle relational database using multimedia resources [10].

In an example from the UK, Beecham et al. [11] described 'CAL-Visual' that was developed at Loughborough University, to support teaching, learning and assessment on construction related disciplines. Visual resources were initially developed under three topics of building defects, building production and construction materials.

7.2 Extrapolations

As seen in the above examples, the techniques and tools that are mobilised in the development of such packages

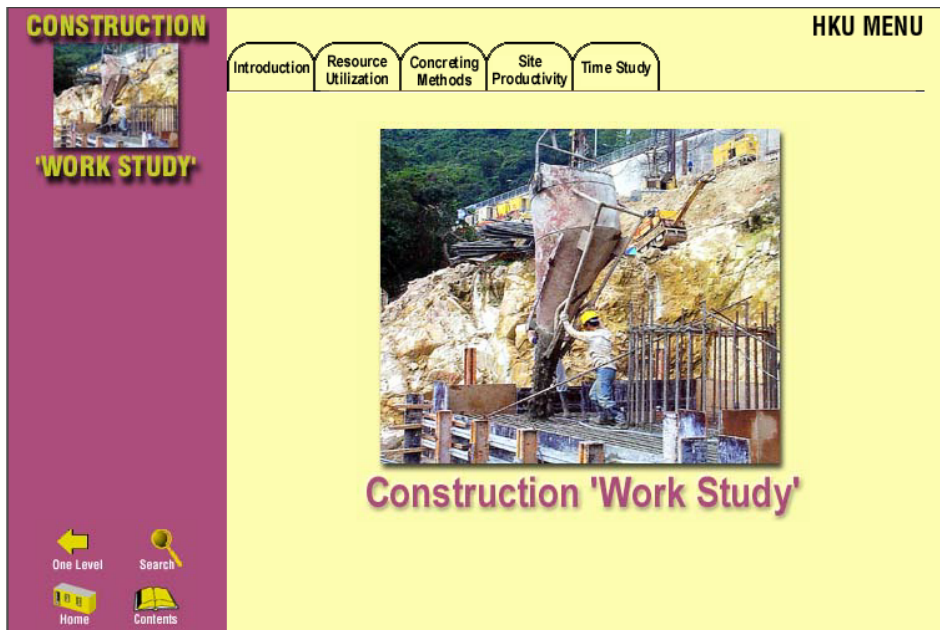


Figure 6. Top page of a typical HKU module on a 'Topic' (Work Study) with tabs leading to sub-topics such as 'Time Study' (as per examples in Figs. 7 and 8)

CONSTRUCTION WORK STUDY

NEW MEDICAL COMPLEX

Concreting Cycle
Multiple Activity Charts

HKU MENU

Introduction Resource Utilization Concreting Methods Site Productivity Time Study

New Medical Complex

Tower Crane Skip Bucket Discharging Concrete Target Column

Lifting Bucket 1 Positioning Bucket 1 Concreting Column Compacting Concrete

Lifting Bucket 2 Positioning Bucket 2 Curing Concrete Recording Data

Data from a Sample 'Column' Concreting Operation:

- Maximum volume of mixer drum in truckmixer: 7 m³
- Actual volume of concrete contained in mixer drum: 6 m³
- Volume of skip bucket: 1½ m³

Figure 7. Thumbnail images and top part of basic Data from a sample Time Study exercise

Viewing Multiple Activities in this Concreting Cycle

Click on the bar below against the item that you wish to see.

| | | | | | | | |
|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|----------------|-------------------------|
| Activity 1 (0:00-1:07) | Activity 2 (1:07-2:05) | Activity 3 (2:05-3:14) | Activity 4 (3:14-6:55) | Activity 5 (6:55-7:46) | Activity 6 (7:46-8:15) | Complete Cycle | Multiple Activity Chart |
|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|----------------|-------------------------|

Activity 4:

Open bucket & Pour concrete.

Sub-activity:

Compact poured concrete with poker vibrators.

| | |
|------------|---------------------|
| Truckmixer | Concreting Crew |
| Idling | Compacting concrete |

Activity duration: 3 min. 41 sec.

Figure 8. Image at the end of a Video Clip that shows one activity in the Concreting Cycle as observed during the Time Study

for teaching-learning in Universities are also evidently used to enhance ‘real-life’ construction management [12], as well as in design/ formulation and analysis of construction through 4D simulations [13]. Meanwhile, ‘VIRCON’ was developed at the University of Sydney as both an educational tool and a construction

management system based on best management practices, using object-oriented programming, CAD systems and virtual reality models [14].

Co-operation between various package developers could be mutually beneficial, apart from opening up

opportunities for on-the-job training, CPD (continuing professional development) and 'knowledge' capture and dissemination. The latter constitute critical components of the increasingly important 'knowledge management' function that is designed to harness the experiential knowledge of an organisation for more efficient 'organisational learning' [6]. 'Value-adding' partnerships between industry and academia may also be forged through such synergistic strategies. While undeniably useful, what appears to be lacking are viable frameworks with working examples of how such partnerships may be launched. CIVCAL provides an example of a tried and tested package that can bring benefits to both academia and industry. Another example of using multimedia technology for construction management training, specifically in the measurement of building works, was cited by Cheung et al. [15].

7.3 Concluding observations

The inter-university multi-disciplinary team that was mobilised to develop CIVCAL, generated useful synergies and provided a valuable learning experience in itself. While each university developed specific topic and project vistas, these are integrated into a comprehensive package. The CIVCAL package thereby provides a wide range of material for assembling/ accessing course-specific aids

for supplementing the teaching-learning of civil engineering, building and construction subjects. The multiple navigational aids assist in efficient access and assembly of project-specific or topic-specific sub-packages, as may be needed for particular teaching or learning assignments.

Although developed for undergraduate teaching in the first instance, the potential applicabilities to organisational learning, on the job training and knowledge management are quite evident. In terms of linkages to organisational learning, learning curves can be considerably 'steepened' and time wasted in re-learning old lessons can be correspondingly 'shortened', by re-visiting vivid multimedia records of past approaches, key process features and linking intelligently to corresponding performance outcomes.

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