

# A User-oriented Web-based Multimedia Programme for Measuring Building Services Engineering Works\*

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*It has been noted that, with the advance in multimedia and information technology, many traditional classroom-based teaching activities have migrated on-line. However, without a proper design framework, a lot of these programmes are just on-line information disseminators. This paper describes a web-based self-learning measurement of building services engineering work programme (MBS) that features the characteristics of three well-established web-based design paradigms: objectivism, cognitivism and constructivism. The programme covers the measurement principles of four of the most commonly installed building services engineering works: electrical installation; heating, ventilation and air conditioning (HVAC); fire services; and plumbing and drainage installations. In addition to the basic contents or measurement rules, the programme is also equipped with a user guide, worked examples, a discussion forum and on-line self-assessments. An evaluation of the effectiveness of the MBS as a learning platform is also provided.*

**Keywords:** web-based; multimedia; building services engineering

## INTRODUCTION

WITH THE INCREASING concern over environmental issues, as well as end-user demands, the design of building services engineering (BSE) works in construction projects has become more and more sophisticated. Furthermore, it is apparent that the cost of building services engineering works has increased at a faster rate than other building components [1, 2]. Proper tendering documentation that facilitates cost control of these installations is therefore essential. In the construction industry, bills of quantity have been used for this purpose by detailing the scope of the work, the materials to be used, and the overall price for the work in one single document. This information is useful in facilitating the contractors' ordering of materials and allocation of resources. Furthermore, the prices contained therein form the basis for evaluating interim payments, variations in the work and the final accounts. Measurement is the foundation building block for compiling bills of quantity. Standardized measurement rules have been developed that aim to maintain consistency in measurement output. Moreover, measurement of BSE works involves the application of standard rules to non-standard system designs. This requires

a good knowledge of the principles underpinning those measurement rules, as well as the necessary skills to master variations of same. The importance of such training is evident in the demand for training courses for practising building services engineers and students.

Effective learning of measuring BSE works is grounded in repeated practice in transforming information from construction drawings to quantities of materials (or components) in different trades with precise and consistent descriptions, in accordance with the Standard Method of Measurement. An integral part of such training is to use continuous assessment to complement lectures. Traditionally, this type of training is delivered through conventional formal lectures and studio-based practice sessions. These, however, are resource intensive. The issue is made more critical as teaching staff with such experience and expertise are not readily available. Therefore, providing alternatives for the effective delivery of building services work measurement courses will be invaluable to both the services engineering industry and academia.

Moreover, the application of standard rules to non-standard designs of building services engineering work is less straightforward than it appears. Students without relevant work experience may encounter difficulties in understanding practical measurement examples and handling hands-on exercises. In this respect, it has been suggested

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that the use of advanced multimedia technology with a web-based delivery platform could provide a more conducive learning environment [3, 4].

Nevertheless, the development of an effective web-based multimedia (WbM hereafter) self-learning programme for building services measurement courses is a task that demands forethought and planning. Previous reviews have argued that the multimedia technology applied in some current WbM self-learning programmes is merely the electronic version of conventionally prepared learning materials (i.e. simple uploading of Words documents and PowerPoint presentations for users to download) [5, 6]. In this respect, the use of advanced multimedia technology aims to provide “multiple sensory modalities” that motivate users to pay more attention to and encourage them to better understand the presented learning materials [7]. Notwithstanding the fact that the web-based environment can accord greater flexibility and control of the venue, time, sequence as well as the pace of learning for users, some still regard this form of delivery as passive [5, 8, 9]. This is because, despite the technology used, many of these programmes still function as information providers instead of providing an environment that encourages students’ active learning [5, 8]. Indeed, the lack of success of this technology may be the result of lack of student feedback loops and self-assessment functions in some currently used WbM self-learning programmes [3]. In response to these criticisms, some programme developers believe that an effective WbM self-learning programme for engineering education does not rest in however promptly and lavishly the multimedia technology in a web-based environment is applied [9]. Instead, more thought should be given to the design paradigm underpinning the programme design [5, 9, 10, 11]. In sum, the design paradigm directs the programme development, which in turn guides the students’ learning process and thus the achievable level of the educational goals [9, 12,13]. Misalignment of this design concept is one possible reason for the failure of some previously developed WbM self-learning programmes [5, 8, 9].

In order to bring about students’ understanding and assimilation of learning materials, Khalifa and Lam [5] pinpointed that WbM self-learning programmes should not merely be developed as an alternative information delivery medium, but should also act as a platform to foster the exploration of information and allow learners to interact with other learners. Their features or special functions should match their respective goals of development [12]. From an engineering education perspective, the principal goals of developing a WbM self-learning programme include: (i) to reinforce students’ continuous practices, (ii) to guide students’ learning progressively, and (iii) to facilitate students to structure the lessons learnt based on enhanced interaction with the instructors and other students [5, 9].

This paper firstly reviews the design paradigms of the WbM self-learning programme and their influence on students’ learning. The link between different design paradigms and features of the WbM self-learning programmes is then discussed. It has been suggested that features that would align the development goals within an established design paradigm should be retained. The MBS described in this study has been designed with this objective in mind.

### DESIGN PARADIGMS OF THE WBM SELF-LEARNING PROGRAMME

In the preceding section, it was argued that students’ learning processes and their level of achievement of the desired instructional goals hinge on the design principles under which a WbM self-learning programme was developed [5, 9, 10, 11]. Notwithstanding the differences in terminology, descriptions and the features of different programmes, the underlying design objectives are anchored in three design paradigms: objectivism, cognitivism and constructivism [5, 13, 14, 15, 16].

Objectivism assumes that the learner’s behaviour is “guided by purpose” and “learning happens when a correct response is demonstrated following the presentation of a specific environmental stimulus” [17]. This is often described as the teacher-centred approach, under which the learning content and pace are controlled by the instructors [9, 13]. Programme features based on objectivism focus on supporting the knowledge and skills transfer to learners and rarely consider the “mental process of learners” [17]. In this regard, the resulting programmes are often described as providing the effective means to present and link course materials. These programmes also support free-access and self-paced learning [15, 18, 19].

Teaching approaches basing on cognitivism emphasize facilitating learners to retrieve, organize, memorize and assimilate learning materials in an efficient and effective manner [6, 15, 17]. Programmes designed on the cognitivism paradigm are characterized by their support aids, such as comprehensive user guides and worked examples [6, 12, 15, 17].

Constructivism emphasizes interaction among learners and instructors, as this “can make learners share their experience and construct their own knowledge” [9]. WbM self-learning programmes developed under constructivism often focus on assisting learners to engage in interaction with the learning content, the instructors and other learners by means of the web-based platform [13]. Features related to the constructivist design include a discussion forum, on-line self-assessment exercises, etc. [6, 12, 15, 17].

It has been observed that WbM self-learning programmes typically carry features characterizing

one or more of the above design paradigms [15, 16]. Nevertheless, Yang and Liu [9] argue that the programme features related to objectivism put too much emphasis on moulding the learners to learn what the designers have pre-determined. Furthermore, the lack of explanation or discussion between the instructor and the learner hampers the learner's understanding of the content in a contextual manner. Khalifa and Lam [5] have also pinpointed the superiority of constructivism over objectivism in terms of the learning outcomes of the students. Conversely, Vrasidas [13] argues that the success of a programme designed with a constructivist approach is dependent on the learner's capability "to manage their learning tasks and engage in interaction with their peers and content". The importance of providing guidelines for use by students may easily be overlooked. Each of the above design paradigms has its own strengths and weaknesses in terms of facilitating the student's learning, and it could be argued that fixing on one particular paradigm may not be the best option when designing WbM self-learning programmes [13].

For example, Khalifa and Lam [5] refer to both objectivism and constructivism in their design of WbM self-learning programmes. Their design could, on the one hand, maintain the necessary guidance for students' learning but, on the other hand, could still facilitate interactive learning [5, 9]. Mishra [16] has developed an online learning programme design framework that integrates objectivism, cognitivism and constructivism. Based on Mishra's design framework [16], Cheung et al. [15] have designed a WbM self-learning programme for construction contracts studies.

The MBS project described in this paper is also based on Mishra's approach [16]. Fig. 1 presents such a framework. The following features are considered essential in developing the MBS:

1. effective presentation and linkage of learning materials;
2. efficient support of free-access and self-paced learning;
3. availability of a user guide;
4. availability of worked examples;
5. availability of a discussion forum; and
6. availability of on-line self-assessment exercises.

#### **DEVELOPING FEATURES USING MULTIMEDIA TECHNOLOGY AND A WEB-BASED ENVIRONMENT**

This section discusses how the features identified in Fig. 1 were incorporated into the MBS through the use of multimedia technology and a web-based environment.

#### *1. Effective presentation and linkage of learning materials*

Realization of this feature involves three major steps. First, the instructor/designer decide on and collect the contents to be presented. Next, he selects the presentation media to be used for learning materials. The final stage involves authoring of the MBS through integrating the learning content from different media into a cohesive presentation [7].

#### **Step 1: Decision and collection of learning contents**

The contents of the MBS are intended for undergraduate students majoring in Building Services Engineering, Construction Engineering and Management, and Surveying to acquire skills in measuring BSE works. The standard measurement rules to be presented in the programme are those commonly used in the industry.

Thus, for the purpose of this project, the following two standard methods of measurement were used as the instructional documents (due to their popularity in construction engineering projects in Hong Kong):

- (a) "Hong Kong Standard Method of Measurement for Building Services" (first edition; May 1993)
- (b) "Hong Kong Standard Method of Measurement of Building Works" (third edition, metric, February 1979)

The following four major BSE systems were selected because they are typical installations in almost all development projects:

- (a) electrical installations;
- (b) heating, ventilation and air conditioning (HVAC) installations;
- (c) fire services (FS) installations; and
- (d) plumbing and drainage (PandD) installations.

#### **Step 2: Presenting media(s)**

The MBS employed the following media to ensure effective presentation of the learning content.

*Text and drawings:* The textual content was extracted from the latest edition of the "Standard Methods of Measurement in Hong Kong". The measurement rules of the electrical, HVAC, FS and PandD works were typed up and the text files were saved to the Learning Materials Management Server (LMMS) in \*.doc format with the designated file names. This filing system ensures efficient retrieval of the necessary files by the designer during the programming stage. Furthermore, drawings that appeared in the MBS were selected from the contract drawings of real construction engineering projects. They were scanned and stored in the Learning Materials Management Server (LMMS) in \*.jpeg format.

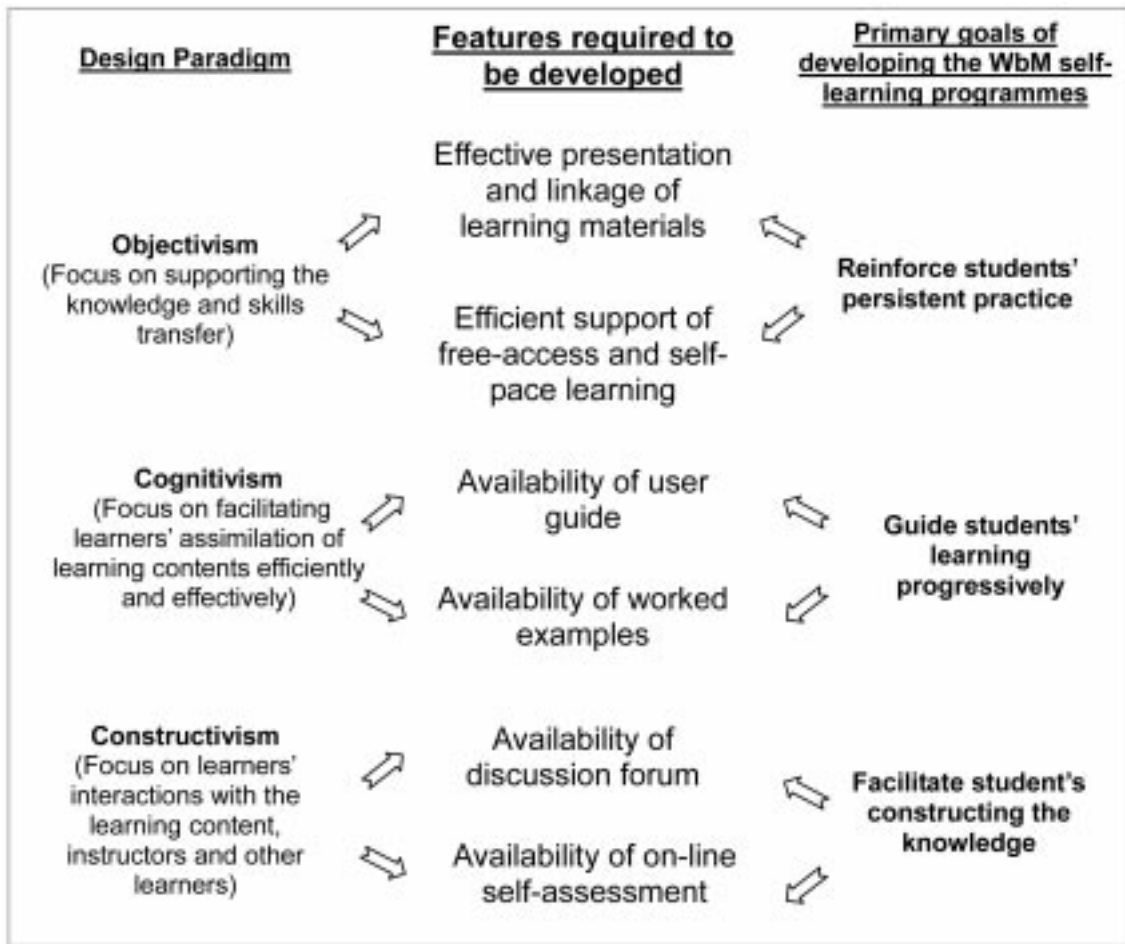


Fig. 1. Identifying features required in the MBS.

*Photos:* In traditional BSE measurement courses, the textual content and drawings were also provided to students during the lectures. Nevertheless, due to their lack of relevant work experience, students often experience difficulty in understanding the textual content of the Standard Methods of Measurement and in visualizing the information contained in the construction drawings through symbols and abbreviations. For example, without visiting the Electrical and Mechanical plant room on site, students may have difficulty in visualizing chillers and chilled water pumps, as well as how they relate to the pipe works in the construction drawings. In response to this problem, digital photos were taken of the installed BSE works. These digital photos help to relate the actual system with the symbols and textual information presented in the drawings. Digital photos in \*.jpeg format were stored with the designated file names in the LMMS for this purpose.

*Graphics:* The graphics for the MBS include the backgrounds, navigation bars and directive buttons. They help in linking the relevant textual context, drawings and photos to the respective interfaces. Graphics of the MBS were designed

and developed using Adobe Photoshop 7.0. All of them were arranged as \*.jpeg images [7, 8].

In MBS, drawings and digital photos stored in the LMMS were further edited in order to “include the special effects and filters to further enhance the appearance” [7]. Adobe Photoshop 7.0 was used for such editing tasks. In order to highlight the item to be measured, animations were added to the drawings by Macromedia Flash.

**Step 3: Authoring of the MBS**

This stage involves integration of the learning materials from different media into a cohesive presentation. Macromedia Flash, a popular authoring tool, was chosen for developing the application and interactive presentation components of MBS [7,8,20,21]. Compared with Visual Basic and Multimedia Tool Book, Macromedia Flash is less complicated in terms of writing programming scripts for animations that can run directly inside the Internet browser [12, 20, 21]. The basic function of the Macromedia Flash could simply be described as placing and linking the relevant textual content, graphics, photos and animations in the multi-track time-line in a planned sequence [8, 20, 21]. Fig. 2 illustrates

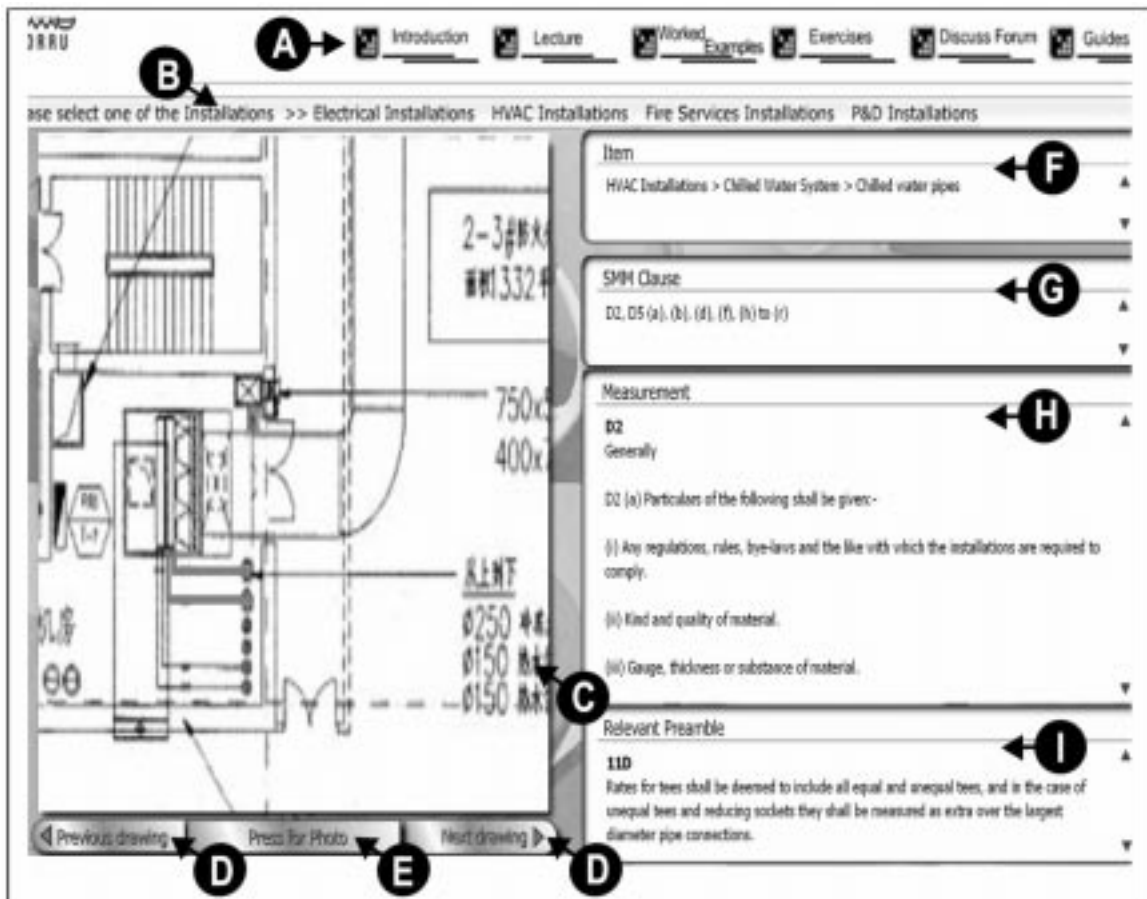


Fig. 2. Integrating the textual and graphical contents of the MBS by Macromedia Flash.

how Macromedia Flash is used to integrate the textual and graphical content into a cohesive presentation for students to learn about the measurement of the chilled water pipes in HVAC installations.

Students who had access to the MBS were assigned specific user names and passwords. After the log-in procedure, a user who wished to learn measurement of chilled water pipes could go through the relevant textual and graphical content using the following steps:

1. Press "Lecture" button from the navigation bar (Area A of Fig. 2)
2. Press "HVAC Installations" button from the menu bar under the navigation bar (Area B of Fig. 2)
3. Press "Chilled Water System" from the pull-down menu of the "HVAC Installations"
4. Press "Chilled Water Pipes" from the sub-menu of the "HVAC Installations > Chilled Water System"

The above steps direct the user to an interface such as that shown in Fig. 2. In this figure, Area C indicates the items to be measured (i.e. the chilled water pipe) with animation highlights in the construction drawings. D is the button for users to retrieve and switch between the animated drawings relevant to the chilled water pipes. Cross-

sectional drawings of the pipes were also provided in order to enhance the students' understanding of the structure and the components of the chilled water pipes. A pop-up window (as shown in Fig. 3) with on-site photos showing the installed chilled water pipes will be displayed when the user presses button E.

Area F, as shown in Fig. 2, indicates the current item (i.e. the chilled water pipes) being selected by the user. Area G displays the relevant Standard Method of Measurement clause(s) for measuring the chilled water pipes. Area H displays the detailed contents of the clause(s) as introduced in Area G. A scroll bar is available for users to view the whole text. In this example, the textual content as shown in Area H indicates that the chilled water pipes should be measured "RUN" (i.e. in meter), including all inline fittings equipment, headers and trapping sets. Area I displays the relevant preamble clauses for measuring the chilled water pipes. The preamble clauses list those works which are inclusive in the unit cost per meter of the chilled water pipes.

## 2. Efficient support of free-access and self-paced learning

The process for supporting students' free access to the learning materials and self-paced learning started when the designers uploaded the

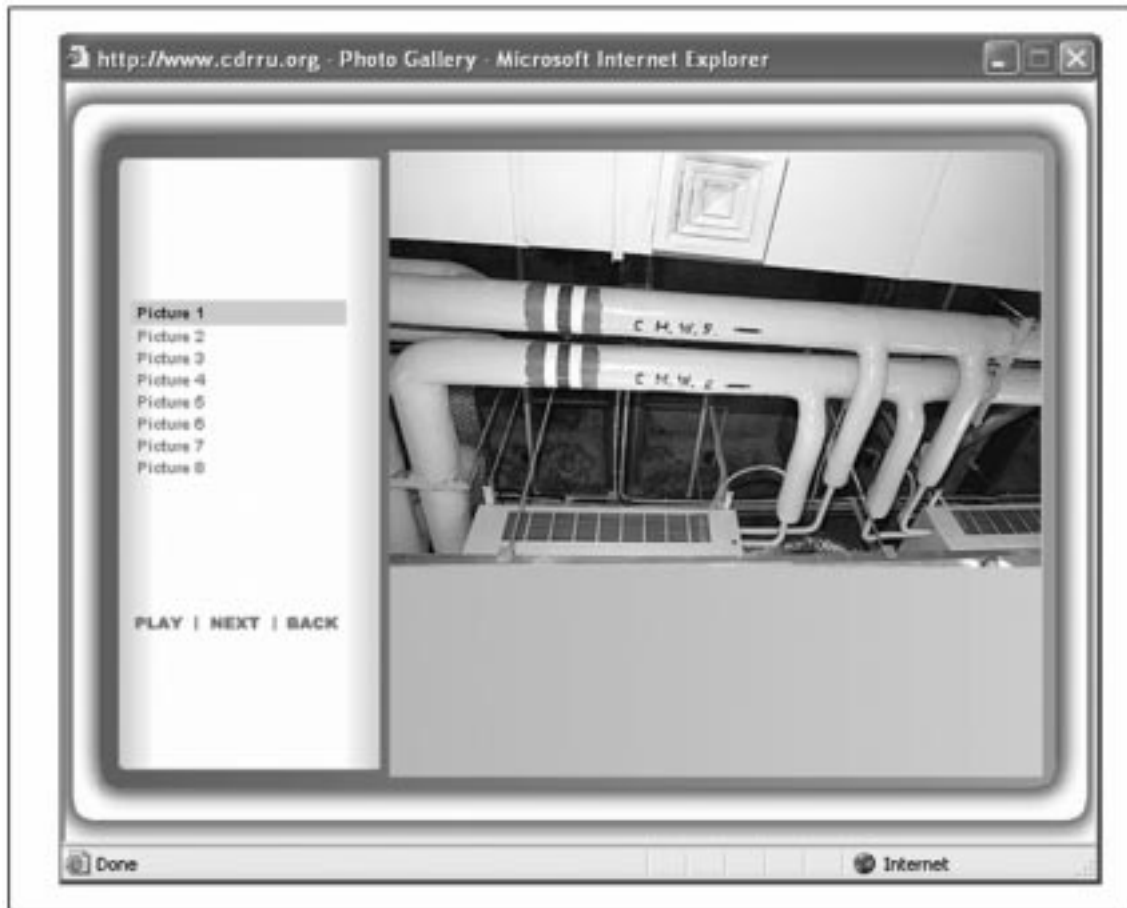


Fig. 3. Pop-up window with on-site photos.

programme developed to the Learning Resources Server (LRS). The LRS operates 24 hours a day. This enables students' learning from the MBS at their own pace, wherever they are and whenever they see fit, by accessing the designated website.

### 3. Availability of user guide

The "Guides to Use" in the MBS provide the necessary information mainly on the operation of the system, and include the hardware and software requirements, etc. The guides give detailed instructions on operating every single section, so that users can fully utilize the facilities provided.

The process of developing the "Guides to Use" began with the programme designer exploring the problems that users may encounter while using the MBS. The content of the "Guides to Use" was then drafted, edited and incorporated into the MBS. To facilitate users' access to the guide, "Guides to Use" buttons are available in both the main menu and the navigation bar of the MBS

### 4. Worked examples

The worked examples aim to illustrate the application of measurement rules through a step-by-step demonstration of the processes involved.

The development process started with the identification of the appropriate textual content and

drawings required for the purpose. After editing and adding the requisite animations of the scanned drawings, the worked example contents were stored in the Learning Materials Management Server (LMMS).

To facilitate the user's access to worked examples, "Worked Examples" buttons are available in both the main menu and the navigation bar of the MBS. Ten worked examples have been developed. Students can pick one of these from the selection menu before entering the example demonstration.

Similarly to the development of the learning materials, Macromedia Flash is used to integrate the textual and graphical content into a cohesive presentation of the worked examples. Nevertheless, different interfaces have been designed to facilitate students' learning from the worked examples.

At the beginning of each worked example demonstration, a picture of the complete drawing (the real drawing is of A0 size) will pop up, to give the user an overview of the whole of the drawing. To embed the necessary script commands to the pop-up drawings, a zoom function is available to the user. By right-clicking the mouse button and selecting "Zoom In" from the pull-down menu, a larger view of that particular portion of the drawing will then be displayed.

The screenshot shows the MBS interface for a worked example titled "Rectangular Air Duct / Insulation & Cladding". On the left, a diagram illustrates the cross-section of a rectangular air duct with external insulation and cladding. Labels in Chinese identify components like the duct, insulation, and cladding. On the right, a data table is used for recording measurements. The table has columns for "length", "not exceeding 0.6m", "not exceeding 0.9m", "not exceeding 1.0m", "not exceeding 1.2m", and "Therm". A "STEP" bar at the bottom indicates the current step in the process.

length	not depicted galvanised steel rectangular air duct				Therm
	not exceeding 0.6m	not exceeding 0.9m	not exceeding 1.0m	not exceeding 1.2m	
Location					
Equipment Ref. ARI-1-01					
100 x 50mm	3				
100 x 50mm	3				
100 x 40mm	2				
100 x 20mm					
40 x 200					

Fig. 4. Worked example of measuring air ducts/insulations and claddings in MBS.

The part(s) of the drawing that were used in the worked example were highlighted. Script commands were also written for the highlighted areas. By clicking on these areas, the user is directed to a step-by-step demonstration of the respective works.

Users can follow the on-screen instructions to go through this comprehensive demonstration. The speed of the demonstration is under the user's control by activating the control bar at the lower right-hand corner. Users can scroll backwards or forwards to review each of them. Fig. 4 shows a screenshot of one of the worked examples in MBS. It shows the sectional details of the air ducts/insulations and claddings and the format of the spreadsheet for the respective measurements.

5. Discussion forum

The "Discussion Forum" (see Fig. 5) provides an opportunity for the user to query the measurement or to discuss or share his/her experience in overcoming some of the problems. The discussion forum provides an interactive platform to users for rapid discussion and sharing.

The discussion forum in the MBS was developed using Macromedia Flash. Students can create their

own threads by clicking "Add Title" to the front page of the discussion forum. They are also free to read the detailed contents of the previous postings through clicking the threads. Users can reply to a particular thread by using the "Reply" button of the thread. The threads are sequenced in descending order in accordance with the posting time in the discussion forum of MBS.

Apart from the above function, users can retrieve previous messages by using the search function at the top of the forum, which categorizes the threads as Name, Title, Date and Content. Users can also define which group of data they want to retrieve. By visiting the forum regularly, the instructor can provide feedback to the questions or discussions posted.

6. On-line exercises

The development process began with selecting the textual content and drawings required for the exercises. After editing and adding the requisite animations of the scanned drawings, the related contents were saved to the Learning Materials Management Server (LMMS). Macromedia Flash was used to integrate the contents from the

Title	Author	Replies	Last Post
<a href="#">Length of Rectangular Air Duct</a>	T.Y. Tong	0	2005-08-26 17:08:52
<a href="#">Worked Example 1 - What is MCB?</a>	K.F. Kam	0	2005-08-26 11:02:02
<a href="#">Taking Off Scheduler</a>	K.P. Siu	1	2005-10-01 14:37:55
<a href="#">Copper tapes in Lightning Protection System</a>	Y.H. Wong	1	2005-09-06 12:16:47
<a href="#">Allowance to cable length in accordance with BSSW/M.C.9.(b)</a>	C.Y. Or	4	2005-09-05 00:28:03
<a href="#">Credits in final circuits</a>	Y.S. Wong	0	2005-08-26 09:49:03
<a href="#">Field equipments in BMS</a>	W.K. Lau	0	2005-08-26 09:34:11
<a href="#">Work by other trades in connection with Mechanical Installations</a>	W.O. Chan	0	2005-08-26 09:32:43
<a href="#">Pipework Fittings</a>	K.S. Wong	0	2005-08-26 09:31:53
<a href="#">Measurement about internal insulation to rectangular ductwork</a>	M.Y. Hung	1	2005-08-28 22:34:04

Fig. 5. A discussion forum in MBS.

LMMS into a cohesive presentation of exercise questions for students.

The process begins with the student carrying out the measurement exercise in the downloaded measurement spreadsheets through referencing the relevant downloaded information and drawings from the "Exercises" page. Students can submit their completed exercise together with their name, student number, email address and login name via the Internet to the web server. The main function of the web server is to divert the sender's work to the instructor's email account and to dispatch the respective answer to the sender after verification of the sender's identity. It is worth mentioning that the web server is capable of completing the process of receiving the student's work to sending auto-reply within seconds. This not only saves time and space for collecting students' work, but also reduces the risk of hard copies going missing. Furthermore, it facilitates students' immediate learning after completion of their task by comparing their submitted answers with the model answers.

### COMPUTING REQUIREMENTS

Table 1 summarizes the hardware and software requirements for the server and the end-user. The

server's hardware is capable of handling at least 100 users' access in a specific time-frame. The MBS portal is based on Java programming and the MySQL data-based backend. Indeed, the Java programming language "has been thoroughly refined, extended, tested, and proven by an active community of over four million software developers" [22]. It is an effective programming language for developing the server-side applications for online forums, stores, polls, HTML forms processing, and more [22]. The end-users' web browser should be supported by Macromedia Flash Player. Apart from this, personal computers available in the market (as well as in the campus area) will be adequate.

### EVALUATION OF THE USE OF MBS

With the goal of investigating the effect of using MBS on students' learning, an evaluation through a questionnaire survey was performed. Students were asked to assess their level of agreement with 12 statements concerning the effectiveness of learning BSE measurement according to their mode of study (1: strongly disagree and 7: strongly agree). The statements concerning the effectiveness of learning were selected from reviews or empirical studies in previous engineering education literature



Table 1. Summary of hardware and software requirements for servers and end-users

Hardware Requirements	Software Requirements
For server set-up	
1. Intel <sup>®</sup> Pentium <sup>®</sup> CPU with clock speed 2.4GHz or equivalent	1. Operation System: Red Hat Linux 7.3 or higher
2. 1 GB double data rate ram	2. Web Server: Apache 1.3.23 or higher
3. 80 GB 7200 resolutions per minute hard disk drive	3. FTP Server: ProFTP 1.2.6 or higher
4. Generic main board with on-board display card and sound card	4. Secure Socket Layer: Open SSL 0.9.6b or higher
5. Generic 10/100 Peripheral Component Interconnect Network Card connected to the internet	5. Secure Telnet Service: Open SSH3.1 or higher
6. Generic integrated drive electronics compact disk rom	6. Programming Language: Java 5.0 or higher
7. Generic floppy disk drive	7. Database Server: May SQL 4.0.16 or higher
8. Generic cathode ray tube/liquid display monitor	
9. Generic keyboard and mouse	
10. Optional uninterruptured power supply (UPS) system	
For end-users	
1. Intel <sup>®</sup> Pentium <sup>®</sup> CPU with clock speed 2.4GHz or equivalent	1. Microsoft <sup>®</sup> Windows 2000 with Service Pack 2, Windows XP Professional or Home Edition, or Windows XP Tablet PC Edition
2. 256 megabytes synchronous dynamic ram	2. Internet browser like Microsoft Internet Explorer <sup>®</sup> 5.5 or higher
3. 100 megabytes or above hard disk drive space available	3. Microsoft Internet Explorer <sup>®</sup> equipped with Macromedia Flash Player.
4. Broadband internet connection	
5. Generic cathode ray tube/liquid display monitor with resolution at 1 024 x 768 px or higher	
6. Generic integrated drive electronics compact disk rom	
7. Generic keyboard and mouse	
8. Generic main board with on-board display card and sound card	

[5, 15, 23, 24]. A sample of the questionnaire is given in the Appendix.

A total of 70 questionnaires were sent to students who had taken a course called "Surveying Studio II" (which contains modules about BSE measurement) in the City University of Hong Kong in the past two years. Forty-four replies were obtained, representing a response rate of 62.9% (see Table 2). Noting that the MBS was officially launched in the academic year 2005–2006, the responses obtained can be classified and compared in two groups: MBS users (students who had taken the course in the academic year 2005–2006) and non-MBS users (students who had taken the course in the 2004–2005 academic year).

In order to examine the effect of MBS on the students' effective learning, mean scores of the MBS and non-MBS users were compared. A statistical method called analysis of variance (ANOVA) was used to identify differences in evaluation between the two groups. As such, the group means are recognized as significantly different when the F-value is high and the significant level ( $\rho$ -value) is lower than 0.05 [25, 26].

The group means, F-values and  $\rho$ -values are shown in Table 3. It was found that the mean scores of all 12 questions concerning the effective-

ness of learning BSE measurement were higher than the mid-point score of 3.5 in a 7-point scale. This could be because, as a whole, the respondents agreed that their modes of learning were effective for them in learning BSE measurement. Nevertheless,  $\rho$ -values of these questions were lower than 0.05. In particular, higher F-values were found in: "Supported my study after lectures and tutorials effectively" (with an F-value of 60.64 at  $\rho < 0.05$ ) and "Provided me a better assessment on my progress of learning" (with an F-value of 53.71 at  $\rho < 0.05$ ). These results indicate that there are significant differences between the MBS and non-MBS users' regarding their degree of agreement on the effectiveness of their modes of learning. Furthermore, comparing the mean scores between these two groups of respondents, MBS users generally gave a higher score for each of the evaluation questions, thus suggesting a higher satisfaction with having MBS to assist in learning BSE measurement.

## RECOMMENDATIONS

The users' evaluation suggested that MBS may help in enhancing the effectiveness of learning.

Table 2. Questionnaire sent and received

Students of Surveying Studio II in academic year	Sent (no.)	Received (no.)	% Received
2004–2005	35	23	65.7
2005–2006	35	21	60.0
Total	70	44	62.9

Table 3. The results of the questionnaire survey

	Non-MBS users	MBS users	F-value	$\rho$ -value
Enabled me to have a flexible pace of learning	3.78	5.19	39.47	0.00
Supported my study after lectures and tutorials effectively	3.83	5.24	53.71	0.00
Helped me to integrate the measurement rules with drawings for measurement works	3.70	5.14	30.71	0.00
Increased self-reliance (i.e. improved my ability to work on my own)	3.52	5.24	40.48	0.00
Facilitated effective communication between instructor and classmates	3.17	5.00	43.55	0.00
Enabled me to complete the tutorial exercises easily	3.74	4.86	14.77	0.00
Guided me to improve my measurement skills progressively	3.61	5.14	28.52	0.00
Provided me a better assessment on my learning progress	3.48	5.24	60.64	0.00
Enabled me to have a better preparation of the examination	3.57	5.10	28.81	0.00
Is an effective way to teach and learn measurement of building services work	3.78	5.24	27.34	0.00
Interested me in learning measurement of building services work	3.57	4.95	20.82	0.00
Improved my measurement skills	3.83	5.00	20.30	0.00

Notwithstanding this, in order to comply with current industry practice regarding measurement, the learning materials of the MBS need to be updated regularly. Furthermore, for routine server administration and learning content updates, an experienced technical staff is required.

### CONCLUDING REMARKS

The design process and features of a web-based multimedia self-learning programme for measurement of building services engineering work (MBS) have been described in this paper. Although the MBS has primarily been developed for use by undergraduate students, it is also suitable for practising engineers and surveyors in administering self-learning so as to enhance their proficiency in measuring building services engineering (BSE) works. Various features of the MBS were developed based on Mishra's design framework [16]. Mishra [16] integrated three well-established design paradigms—objectivism, cognitivism and constructivism—in his on-line programme design framework. Programme features suggested by these design paradigms include: effective presenta-

tion and linkage of learning materials; efficient support of free-access and self-paced learning and the availability of a user guide, worked examples, a discussion forum, and on-line exercises. Adopting Mishra's design framework ensures that the features developed using multimedia technology and a web-based environment could achieve the primary programme goals of the MBS. Utilizing multimedia in presenting the construction drawings, site photos and the measurement rules in a sequential and organized manner, students can study and practise building measurement through the comprehensive course materials, user guides, worked examples and on-line assessments. Based on the results of the questionnaire survey, the use of MBS to facilitate students' learning on BSE measurement can be justified. Notwithstanding this fact, this paper is not intended to play down the role of face-to-face teaching. Nevertheless, it demonstrates how multimedia technology and a web-based environment could complement classroom study of BSE measurement.

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**APPENDIX: SAMPLE OF QUESTIONNAIRE**


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**Part 1 Personal Information**

Please fill in the information (or circle the appropriate choice) for each question

- Q1.1 Were you a student of the course BC4316 (Cost Management for Engineer) or BC4315 (Surveying Studio II)?  
 a) Yes                      b) No
- Q1.2 I took this course in academic year  
 a) 2005–2006              b) 2004–2005
- Q1.3 Mode of study  
 When I took this course, I was given:  
 a) Lectures, tutorials and lecture notes  
 b) Ditto + an access to the Web-Based Multimedia Self-Learning Programme for measurement of building services work (MBS)

**Part 2 Effectiveness of Learning**

*Part 2.1 Regarding the mode of learning (as circled in Q1.3), circle the number that best reflects your opinions: (1 represents "Strongly Disagree" and 7 represents "Strongly Agree")*

**The mode of study (as circled in Q1.3):**

- |      |  |               |
|------|--|---------------|
| Q2.1 | Enabled me to have a flexible pace of learning                                   | 1 2 3 4 5 6 7 |
| Q2.2 | Supported my study after lectures and tutorials effectively                      | 1 2 3 4 5 6 7 |
| Q2.3 | Helped me to integrate the measurement rules with drawings for measurement works | 1 2 3 4 5 6 7 |
| Q2.4 | Increased self-reliance (i.e. improved my ability to work on my own)             | 1 2 3 4 5 6 7 |
| Q2.5 | Facilitated effective communication between instructor and classmates            | 1 2 3 4 5 6 7 |
| Q2.6 | Enabled me to complete the tutorial exercises easily                             | 1 2 3 4 5 6 7 |
| Q2.7 | Guided me to improve my measurement skills progressively                         | 1 2 3 4 5 6 7 |
| Q2.8 | Provided me a better assessment on my learning progress                          | 1 2 3 4 5 6 7 |
| Q2.9 | Enabled me to have a better preparation of the examination                       | 1 2 3 4 5 6 7 |

**Generally, the mode of study (as circled in Q1.3):**

- |       |  |               |
|-------|--|---------------|
| Q2.10 | Is an effective way to teach and learn measurement of building services work | 1 2 3 4 5 6 7 |
| Q2.11 | Interested me in learning measurement of building services work              | 1 2 3 4 5 6 7 |
| Q2.12 | Improved my measurement skills   | 1 2 3 4 5 6 7 |
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