CMAR: A Conceptual Framework for Designing Mobile Augmented Reality Learning Module for Construction Measurement

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Abstract. Augmented Reality (AR) is a technology that allows two- or three-dimensional computer-generated graphics, objects, and information to be displayed as an overlay onto the real environment. With the advancement of mobile devices in term of their sensors (gyroscope, barometer, accelerometer, proximity sensor, camera module), displays and processing power, the potential of using mobile AR in teaching and learning (T&L) is becoming clearer. Construction measurement subject is considered the core subject for a quantity surveying student to master. However, some of the measured elements are difficult for students with low spatial skills to visualize the construction sequence and understand. Therefore, the use of AR would help in enhancing the T&L experience of construction measurement for the students. This paper aims to propose a conceptual framework for designing a mobile AR learning module for construction measurement subject. The Construction Measurement Augmented Reality (CMAR) framework consist of the learning theory, learning content, features and learning outcome.

Keywords: Augmented reality · Construction measurement · Quantity surveying education · Mobile application · CTML

1 Introduction

Mobile devices such as smartphones and tablet are omnipresent in this era. Smartphones have been moulded into a part of people daily life especially students. Students nowadays are not only equipped with smartphones, but they are also technologically literate [1]. Scholars believe that utilizing technology in the teaching and learning process could help in understanding and the learning process [2]. Scholars have suggested that educators

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take advantage of the technology that the students are interested in, this is to capture their interest in the learning process.

Therefore, with the implementation of mobile AR, the educators could capture the student's interest in the subject. With the mobile device's advancements in term of sensors (gyroscope, barometer, accelerometer, proximity sensor, camera module), the use of AR could be beneficial. Other than that, the combination of 3D models in the teaching and learning process has been proven beneficial in teaching construction-related subjects due to the ability of computer-generated graphics to realistically represents the building element. With mobile AR, students can use AR as a learning tool because AR application can be made to be used with a smartphone. Therefore, the AR application is easily accessible.

However, despite the various advancement of technology, the teaching and learning process of construction measurement has been limited to the traditional approach which has minimal use of technology [3]. Construction measurement is defined as a skill to interpret drawings, the knowledge of construction technology and the understanding of the standard method of measurement (SMM) and construction measurement is deemed to be one of the most important skills for a quantity surveyor to acquire [4, 5]. Students have to acquire adequate knowledge and understanding of the construction technology to identify the elements and help visualize the construction process [6].

Furthermore, the lack of content specifically for AR is lacking not only in the context of construction measurement but in any other body of knowledge. Therefore, to incorporate AR with construction measurement teaching and learning, this study focused on the conceptual framework needed to design a learning module for construction measurement. To develop the proposed conceptual framework, these objectives are outlined:

1. To discover relevant learning theories associated with AR
2. To identify what features needed to be included in the AR application
3. To identify what is the syllabus for the construction measurement course
4. To determine the expected learning outcome of learning construction measurement using AR

2 Conceptual Framework

The conceptual framework is proposed to be used in designing a mobile AR learning module for construction measurement. The use of AR, CTML, relevant features and construction measurement syllabus would complement the learning process of construction measurement and make learning more effective and accessible. These are the components that would be included in the conceptual framework.

2.1 Cognitive Theory of Multimedia Learning (CTML)

This study incorporates the cognitive theory of multimedia learning (CTML) as the foundation/learning theory of the framework. Shirazi and Behzadan [7] describe the cognitive theories of multimedia learning as three fundamental concepts in the science of learning. Before developing learning tools, it's important to understand how the human information processing system works [8].

As shown in Fig. 1, humans process information across channels and store it in three forms of memories. First is the dual-channel which states that humans have separate channels for processing verbal and visual content or learning materials. Second is the limit of capacity which a person can process a limited amount of material in each channel at one time. The third is active processing where indicates that meaningful learning had occurred when learners are engaged in appropriate cognitive processes during the learning session.

CTML is a simple interpretation of how the human information processing system functions. There are three different sections where different types of memory are stored, as shown in Fig. 1. The sensory memory is the first part, and it focuses on information collected in the same sensory format provided to the user. The sensory memory has a broad memory capacity but only lasts for a short period. Working memory is the second component, which stores and organizes information in a small capacity. Working memory often stores information for a brief period. According to Ebbinghaus [9], long-term memory retains information in an ordered format, has a wide capacity, and lasts for a long time.

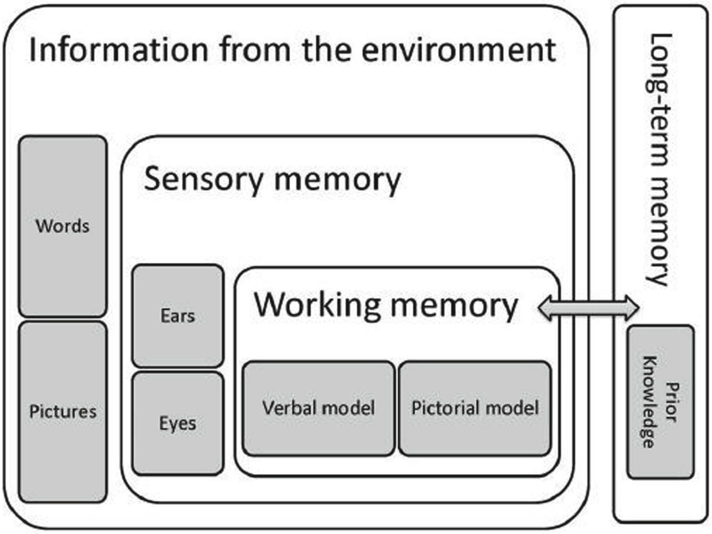


Fig. 1. Cognitive structure and information processing model [5]

Based on these theoretical assumptions, Mayer [11] has developed the principles to design an effective multimedia instruction which includes 12 principles to design an effective multimedia learning module. According to Mayer [11], CTML supports the arguments that students learn better with audio and visual representation together rather than audio or visual alone. CTML provides a framework for improving how students learn with the involvement of technology. CTML provides these design principles for the creation of multimedia instructional technology that focuses on efficiently responding to student's cognitive load. The design principle by Mayer [11] is shown and explained in the table below. These design principles were used as the theory for this study to design a better experience of using AR in construction measurement teaching and learning (Table 1).

Table 1. Mayer's [10] 12 design principle for multimedia instructions

Design principle	Explanation
The coherence principle	When there isn't any extraneous, distracting content, humans learn better
The signalling principle	When humans are shown exactly what to pay attention to on a display, they learn more efficiently
The redundancy principle	People learn more effectively when narration and images are used instead of narration, graphics, and text
The spatial contiguity principle	When related text and visuals are physically close together, humans learn better
The temporal contiguity principle	When related words and images are viewed together rather than sequentially, humans learn better
The segmenting principle	When knowledge is viewed in fragments rather than as a continuous stream, humans learn better
The pre-training principle	Humans learn more easily if they are already acquainted with some of the fundamentals
The modality principle	Humans learn more easily from images and spoken words than from written words
The multimedia principle	Humans learn more easily from both words and pictures than from only words
The personalization principle	Humans learn more from a conversational, casual tone than from a formal tone
The voice principle	A human voice is more effective than a machine voice in teaching humans
The image principle	Humans do not always understand better from a video of another person

There are several scholars [12–21] who discuss the use of the CTML design principle for AR and agrees that not all of Mayer's CTML design principle is included in their use of AR. These scholars only use signalling principle, spatial contiguity principle, temporal contiguity principle, modality principle and multimedia principle in their study and this shows that the principle used is suitable to be used in AR environment.

2.2 Features to be Included in CMAR

The conceptual framework is designed to be used as a mobile application that involves in integrating the mobile device and the multimedia contents. The use of 3D models, computer-generated graphics, 3D text, audio, and video are implemented into the application to generate an AR environment. The inclusion of 3D objects could help in aiding the students in the visualization of the construction elements.

However, to use AR for teaching and learning construction measurements, other features needed to be included to deliver the content. These features were identified by interviewing quantity surveying educators from universities all over Malaysia. The educators interviewed have over 5–10 years of experience in teaching construction measurements. The identified features are that were deemed important to use in teaching and learning construction measurement using AR are:

1. Annotation – extra information on the 3D models (building elements, units)
2. Specifications – Building specifications, materials specifications, and dimensions of the building elements
3. Interactive video – on the construction sequence, construction process of the building elements
4. 3D Models of the building elements
5. Measurement rules – clauses based on Malaysian Standard Method of Measurement 2
6. Guideline to measure the building elements

2.3 Syllabus

Construction measurement is often taught concurrent construction technology. The dominant timing of teaching construction measurement is concurrent, in which construction technology is taught before construction measurement. Therefore, the syllabus from construction technology and construction measurement was included in the conceptual framework.

The syllabus of construction technology and construction is obtained from the Board of Quantity Surveying Malaysia (BQSM) academic accreditation requirements. The academic accreditation requirements show the topics that were taught in the course and the requirements are used in all universities that offer quantity surveying program. Therefore, the conceptual framework could be used by other universities in Malaysia to develop their CMAR teaching module. Table 2 shows the syllabus that is extracted from the BQSM academic accreditation requirements. The syllabus is the content of the learning module for teaching construction measurement using AR.

Table 2. Construction measurement and construction technology syllabus [22]

Syllabus	
Construction measurement	Construction technology
Intro to measurement (History & Development, QS roles, Intro to SMM, Principle of measurement	Intro to construction technology (Review on construction process, roles of building and design team, classification of work, building trades and elements)
Site preparation	Site preparation and soil investigation
Simple Substructure works - Excavation and foundation	Foundations (Shallow foundations, Piling, Basement)
Internal & External Wall (Brick, block, masonry, precast panels)	Wall and partition (Brickwork, blockwork, masonry, precast panel)
Finishes (Ceiling, wall, floor)	Timber structure (Frame, floor, wall, staircase, roof structure and coverings)
Timber roof (Structure, coverings, drainage)	Reinforced concrete (frame, floor, flat roof, wall, staircase, ramp, precast concrete)
Door and Window	Door and window
Reinforced concrete (Substructure, Frame, Upper floor, Staircase, Roof)	Finishes
Precast concrete (IBS component)	Steel structure
Services Installation (Plumbing & Sanitary, Mech. Engineering, Electrical Engineering)	Demolition and alteration, temporary works
Structural steelwork	External works
Piling works	Civil engineering works
Basement works	Marine and offshore structure
Demolition & alteration works External works Prime cost sum Provisional Sum Preliminaries	Building materials (Concrete, brick, block, masonry, waterproofing and asphalt, roofing, woodwork, structural steelwork, metalwork, finishes, glazing, painting, and decorating, sanitary fitting, and plastic products
Civil measurement	Draughtsmanship
Computer-aided measurement	
Specifications and preambles	

2.4 Student's Actual Use

The input from students was collected by using a questionnaire and is based on the technology acceptance model (TAM) [21]. The construct that was used to evaluate the student's actual use is perceived usefulness (PU), perceived ease of use (PEOU), behavioural intention and attitude (BIA), self-efficacy (SE), subjective norm (SN) and teacher factor (TF).

A total of 332 students from universities that offers quantity surveying participated in answering the questionnaire. Based on the questionnaire results, students intended to use the AR application as a mean to visualise the construction sequence, acquire knowledge, knowledge processing and group sharing.

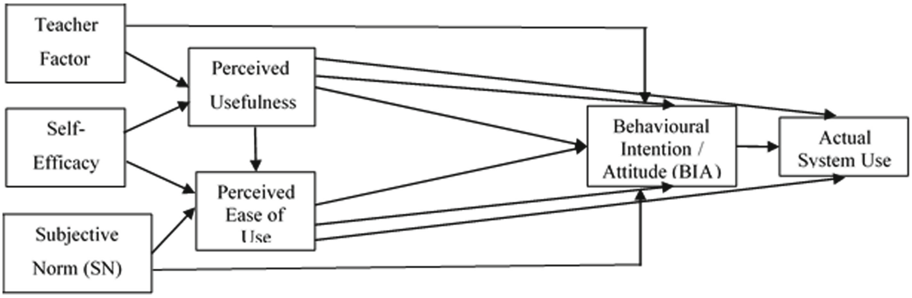


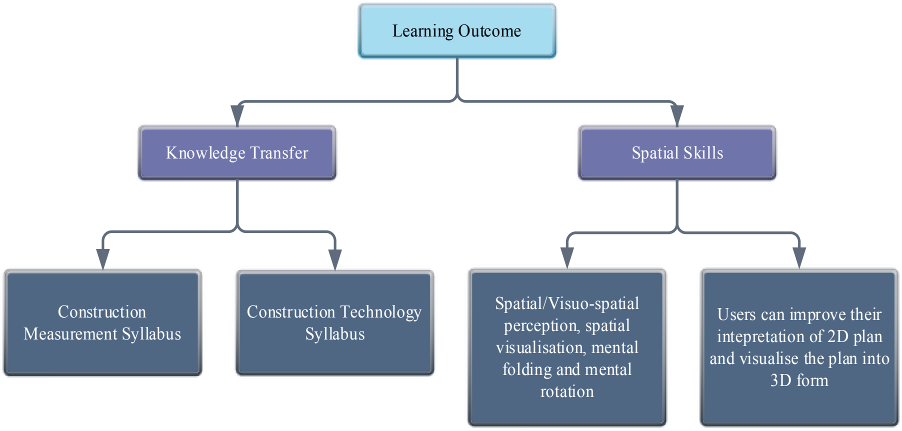
Fig. 2. Proposed technology acceptance model

However, because of the similar attributes of the actual use, acquire knowledge, processing information and group sharing were combined to form knowledge acquisition. With the proper implementation of AR content and designing the syllabus, the intended actual use of the students could be achieved. Therefore, the integration of AR content would enhance the students understanding and learning experience of construction measurement.

2.5 Expected Learning Outcome

Two outcomes are expected from the CMAR framework, which are knowledge transfer and spatial skills. Based on other studies conducted with AR [12–21], most of the expected learning outcome is the transfer of knowledge and spatial skills enhancements. Students are expected to gain knowledge from the AR application and achieve the expected learning outcome from the two syllabus which is construction measurement and construction technology.

For the spatial skills, students are expected to improve their spatial/visuospatial perception, spatial visualisation, mental folding, and mental rotation, with these skills enhanced, students can improve their interpretation of 2D drawing plan and visualise the plan into 3D form. These spatial skills are beneficial for students in construction measurement because it is expected for students to be able to visualise the elements and interpret the construction drawings.



2.6 Proposed Conceptual Framework

The CMAR application is designed to enhance the learning experience of construction measurement. With the accessibility and usability of the application, students could learn and store notes on construction measurement ubiquitously. Figure 2 shows the conceptual framework for designing a learning module for construction measurement using AR. The components of the CMAR conceptual framework involves:

1. Mayer's CTML Design Principles – 5 Design principles for learning using AR. These design principles help educators in designing the learning module based on the design principles requirements.
2. Syllabus – construction measurement and construction technology course outline, the inclusion of construction technology is because the subject is taught concurrently.
3. Features –the application should include these required features. These features were stated by the educators and deemed important in learning construction measurements.
4. Student's Actual Use – This section refers to the student's true intention to use the technology.
5. Learning outcome – Refers to the expected learning outcome when using CMAR which is knowledge transfer and improvement of spatial skills (Fig. 3).

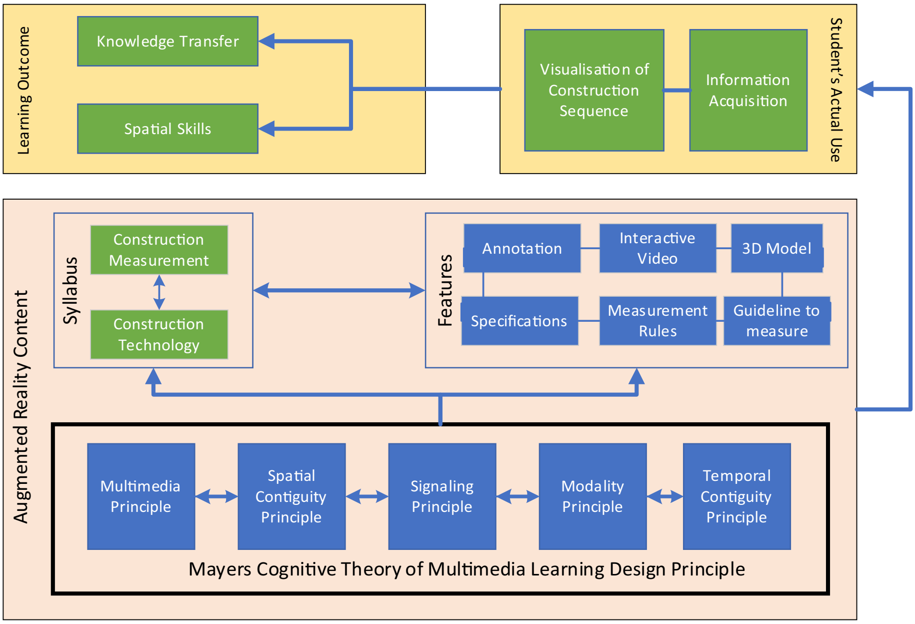


Fig. 3. Framework for designing construction measurement learning module using AR

3 Conclusion

The framework and prototype for applying AR into the teaching and learning of construction measurement are achieved from all findings from the previously stated research objectives. The framework comprises learning theory, features, syllabus, student's actual use and learning outcome as the components. The learning theory implemented into the framework is the Mayers cognitive theory of multimedia learning as the foundation for the framework. The design principles from the theory are selected to fit the use case for the study which is specifically used for AR. The expected learning outcome from the use of AR would be reflecting the whole framework. The combination of learning theory, features, syllabus, student's actual use and learning outcome is essential in developing the framework.

The research findings contribute toward the understanding of cognitive and technology-aided learning which results in a more updated and effective learning experience. AR could be used as an educational tool to enhance learning effectiveness, improve the learning environment, and have ubiquitous access to the learning material.

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