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Design A Situated Learning Environment Using Mixed Reality Technology - A Case Study

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Abstract**—**Mixed Reality (MR) is one of the newest technologies explored in education. It promises the potential to promote teaching and learning and making learners' experience more "engaging". However, there still lack of research on designing a virtual learning environment using MR technology. In this paper, we describe the Mixed Reality technology, the characteristics of situated learning as instructional design for virtual environment using mixed reality technology. We also explain a case study that implemented those design and also the system overview.

Keywords**—**authentic activity. authentic context, mixed reality, situated learning

I. INTRODUCTION

VIRTUAL Environment (VE) can be defined as a 3D data set describing an environment based upon real world or abstract objects and data [1]. The term virtual environment also refers to a Virtual Reality (VR) which uses of computer graphics systems in combination with various display and interface devices to provide the effect of immersion in the interactive 3D computer-generated environment. VE used specifically for educational purposes can be referred to as Virtual Learning Environment (VLE) [2]. Augmented Reality (AR) or Mixed Reality (MR) technology can be used to create the sensation of virtual objects that are present in the real world. To achieve the effect, software combines VR elements with real world [3]. A VLE created using VR or MR technology not only provide rich learning patterns and teaching contents, but also helps to improve learners' ability to analyze problems and exploring new concepts. The range of words that users can explore and experience in a VE is unlimited, ranging from factual to fantasy, set in the past, present or future [4]. MR technology in education can be considered as the next generation blended learning environment that is realistic, authentic, engaging and extremely fun.

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However, even though MR systems are becoming more prevalent, until now most development is still technology driven and the research is mainly focused on how to overcome hardware and software issues [5]. It is hardly easy to find guidelines or frameworks on designing of VR or MR systems as learning tools [6]. Even though there is no clear evidence that any medium could bring added values to learning, nevertheless carefully designed instruction that utilizes advantages of what virtual technologies offer can bring added value to learning [7][8]. In this paper, we intend to describe the design of MR system using situated learning model to promote understanding on scientific research.

II. RELATED WORKS

A. Mixed Reality Technology

There are a few common accepted definitions of AR or MR. MR system can be defined as a system that combines real and virtual, interactive in real time and registered in three-dimensions [9]. Brett [8] explained that AR interface combines aspects of virtual reality and the real-world environment by providing a person a chance to view one or more virtual 3D objects in real-world space. Others like Milgram describes a reality-virtuality continuum that spans from the real environment to a pure virtual environment [10]. In between there is MR which consists of Augmented Reality (closer to the real environment) and Augmented Virtuality (closer to the virtual environment) as shown in Fig. 1.

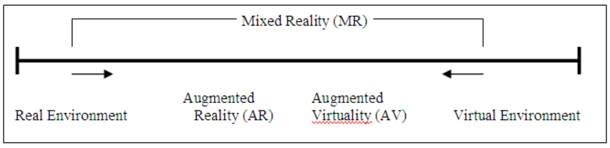

Fig. 1 Milgram Reality-Virtuality Continuum

With those characteristics, the educational experience offered by MR is different from other technologies. This is because it can support the seamless interaction between real and virtual environments, allowing the use of a tangible interface metaphor for object manipulation and the ability to transition smoothly between reality and virtuality.

Some of the significant values of the MR applications in learning are :

- *Draws people's attention*: As a new technology, MR draws people's attention. Drawing students' attention is an important factor in instruction [11].
- *Constructivist learning environment* : MR technology can be used to create a constructivist environment to enhance learning [12]. In [13], Chen used AR as an alternative way to view the chemistry world and allowing students to interact with the system and discover knowledge on their own.
- *Sensorimotor feedback*: MR can increase reliance on sensory information, allowing users to interact with the system by using their body, especially hands which provides 'sensorimotor feedback'. Users also can obtain a sense of spatial feeling [14].
- *Authentic Learning*: The question of authenticity hinges on the context in which the task can be perceived as authentic. The main idea of authentic learning is to provide real materials and real activities. MR ability to annotate real elements and the ability to add to reality by superimposing virtual aids, will aid in instruction and learning for those disciplines where a specific spatial configuration of elements must be learned and remembered.
- *Realistic models*: AR provides a means of "seeing" phenomena in 3D, thereby bringing the contextual three dimensional nature of the real world to the their learning. Textual and pictorial information in the typical two-dimensional print-based resources loses much of the richness of the "real" world elements, and involves an element of interpretation that is rather difficult for some students.

B. Augmented Book

Electronic book can be an electronic version of a traditional text (online interactive book and electronic book readers) or traditional book with electronic features (audio book and multimedia CD ROM book). In [15], Marshall et al. have shown that users still love the physicality of a real book because it offers a broad range of advantages, such as: transportability, flexibility, robustness, etc. However, the traditional textbooks, novels, magazines, and any form of printed publication suffer from two weaknesses - inability to directly portray three-dimensional (3D) objects, and the inability to convey time evolving information in a dynamic way such as showing motion [16].

These factors undoubtedly support research into another future for books : digitally augmenting and enhancing real books. This combines the advantages of physical books with new interaction possibilities offered by digital media. One type of visually enhanced books is the use of AR or MR technology which known as AR or MR book [17]. AR or MR book is an interactive paper implementing some form of physical-to-digital links where physical artefacts particularly paper documents become augmented with digital information. Fig. 2 shows the class of augmented books according to their physicality [17].

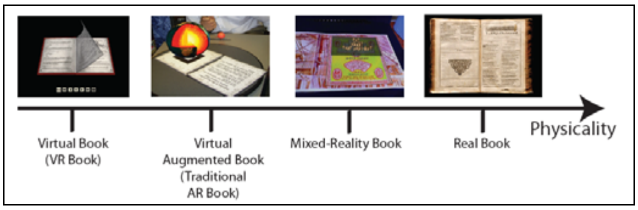

Fig. 2 The Physicality Continuum

C. Learning Principles

Developing any medium of effective materials that helps facilitate learning requires an understanding and appreciation of the principles underlying how people learn. One of the related basic principle of learning is social constructivist approach which emphasizes that learning occurs through sensory experiences and interaction with the environment. This statement was supported by traditional sensory stimulation theory which propounds as its basic premise that effective learning occurs when the senses are stimulated. Laird quotes research found that the vast majority of knowledge held by adults is learned through seeing (75%), hearing (13%) and the other senses - touch, smell and taste (12%) [18]. By stimulating the senses, especially the visual sense, learning can be enhanced. Moreover, this theory says that if multi-senses are stimulated, greater learning takes place. Stimulation through the senses is achieved through a greater variety of colours, volume levels, strong statements, facts presented visually and the use of a variety of techniques and media.

Most students face difficulties in their studies because of the factors associated with their development of appropriate mental models. To master the abstract science concepts, learners should be able to build generic and runnable mental models which often incorporate invisible factors. Unfortunately, they find it difficult identifying important factors or imagining new perspectives. They also lack of real-life analogies upon which to build their mental models [13]. Consequently, most learners—including many science majors—still face difficulty in understanding science concepts and models at the qualitative level, let alone the problems that occur with quantitative formulation. These misconceptions, based on a lifetime of experience, are very difficult to remediate with instructionist pedagogical strategies. Substantial research indicates that traditional lectures and laboratory sessions are not adequate for teaching difficult science concepts.

Mental models very often do not adequately explain the phenomena and need to be explicitly changed through appropriate instruction to be able to represent the phenomena adequately. In [19], Sopiah also added that the methods of instruction in physics, biology and science should emphasize the development of scientific reasoning skills, as these skills are required for conceptual understanding. Dede [13] mentioned a few methods to help learners master complex scientific concept : attract learners to engage in the learning activities, using meaningful representations, using multiple mapping of information and additionally learning-by-doing.

Besides that, in order to help learners develop good mental models is by providing them with conceptual models [20]. Whereas a mental model exists in a learner's mind, conceptual models are devices presented by teachers or instructional materials. Computer diagram, animations, and video presentations have all been suggested as means of providing conceptual models that help develop learners' mental models. This clearly suggests that virtual learning environment that incorporates multimedia technology has great potential for developing mental models [21].

D.Situated Learning Principles

Social constructivist is a theory where learning occurs most effectively in authentic setting and involving social interaction. One of the well known social constructivist approach is situated learning, which has made a significant impact on educational thinking since it was first expounded by Brown, Collins and Duguid in 1989. Situated learning is embedded within and inseparable from participating in a system of activity and deeply determined by a particular physical and cultural setting and also interaction with their social teams which lead to their adoption of learned behaviors [22]. In contrast with most classroom learning activities that involve abstract knowledge which is and out of context, Lave [23] argues that learning is situated; that is, learning is embedded within activity, context and culture and call this a process of "legitimate peripheral participation". Among others, Albert Bandura is considered the leading proponent of the social learning theory, where he elaborates that learning is a social process, explaining that we learn everything vicariously before we learn it directly because it is the only way we can "acquire large, integrated patterns of behavior without having to form them tediously by trial and error" [24]. Dede in [25] mentioned that the harder the task to be learned, the more we must learn it through observation first.

Technology can play an important role in integrating 21st century skills and mediating authentic experiences in the classroom by facilitating the creation of communities of practice and incorporating many of the tools that practitioners use around issues of current scientific concern [26]. Simulations and virtual reality provide the basis for one form of situated learning by modeling specific aspects of real-world complex systems, allowing learners to experiment with the system either by manipulating parameters or participating inside the system and observing outcomes. Simulations situated in rich, realistic 3D virtual worlds might be described as ''heavily'' virtual. These simulations are certainly engaging, but they depart so much from the actual world that they may feel less authentic. Learning environments that are ''light'' on virtual information, by contrast, provide less simulated sensory input, but remain closer to the actual world and can take advantage of its affordances for authenticity [27]. MR plays the role of balancing the strengths and weaknesses of virtual media in creating authentic learning environments and to ''lightly'' structure activities that take advantage of the authenticity of real-world environments together with live social interactions with other participants.

E. Characteristics of Situated Learning

The literature reveals a number of case studies, and some research, that support the contention that the situated learning approach can be used successfully as a model of instruction [28]. Since there are a variety of technologies exist, many different characteristics of situated learning have been defined. Lunce in [29] which using simulation to model the situated learning, defined four concepts for simulating situated learning:

- Learning takes place in a specific context and the context significantly impacts learning
- Collaborative process in which the student interacts with other members of a "community of practice" The relationships among members of such communities tend to be peer-based rather than the more formal teacher-student relationship of the classroom
- The assumed presence of tacit knowledge
- Everyday cognition is an integral part of situated learning and refers to the process of learning to use a tool or artifact in a real-life situation to accomplish a real-world objective.

Herrington et al. [30] described nine characteristics of situated learning for multimedia and online learning:

- Authentic context that reflects the way the knowledge will be used in real-life
- Authentic activities
- Access to expert performances and the modeling of processes
- Multiple roles and perspectives
- Collaborative construction of knowledge
- Coaching and scaffolding
- Reflection to enable abstractions to be formed
- Articulation to enable tacit knowledge to be made explicit
- Integrated authentic assessment

Hillary McLellan in [31] defined the key component of situated learning model as : stories, reflection, cognitive apprenticeship, collaboration, coaching, multiple practice, articulation of learning skills and technology. However, McLellan's reemphasizes that knowledge must be learned in context. This can be the context of (i) the actual work setting; (ii) a highly realistic or 'virtual' surrogate of the actual work environment ; or (iii) an anchoring context such as a video or multimedia program.

There are different opinions on the main factors that may affects the situated learning. Lave and Wenger in [22] defined that situated learning as resulting from the interaction of three areas of influence: agent, activity, and world. In terms of the instructional design of interactive multimedia, the critical characteristics of situated learning can also be examined within a framework of the roles and responsibilities of three mutually constitutive elements of the learning process: the learner, the implementation and the interactive multimedia program [23].

III. CASE STUDY : MIXED REALITY REGENERATIVE CONCEPTS (MRRC)

This *Mixed Reality Regenerative Concept* (MRRC) is an MR application that integrate some components of the situated learning as a model of instruction. Combination of real and virtual environment and supported by 3D graphics, animation, text, narration and music, this MRRC application will give the users (Biomedical students) some exposure on the regenerative concept and in-vitro process of animal tissue culture. MRRC adapts the MagicBook concept which functions as a reading material, a menu and displaying 3D virtual and animated content registered on real pages. Users navigate the system by flipping through the page book. MRRC also uses markers as tangible interfaces which serves as physical handlers in interacting with virtual object. The advantage of tangible interfaces is that it does not require any special-purpose of input device and thus provides an intuitive and seamless interaction with digital and physical object.

To design situated learning using MR book technology there are three main elements to be considered namely: context, activities/task and users (Fig. 3).

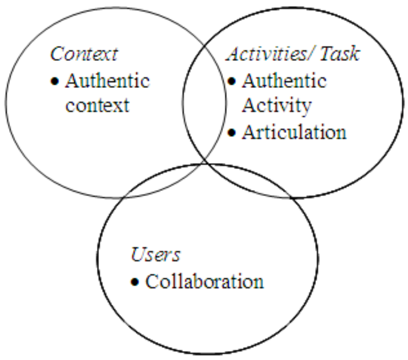

Fig. 3 Constitutive elements of situated learning in MR system

Context will be considered as the real working environment or as the physical environment, social/other people, temporal/time constraint, infrastructural and tasks. Activities can be defined as the real task to be completed. Users will be students that will use the system.

A. Situated Learning and Instructional Design

This case study looks at how situated learning can be supported by MR technology as instructional design. MR book has been used as a tool to show the scenario in a laboratory. The characteristics of situated learning and the instructional design implications are discussed on Table 1.

TABLE I
CHARACTERISTICS AND INSTRUCTIONAL DESIGN

Elements	Characteristics	Instructional Design Implications
Context (Equipment and environment)	Authentic context	The user will read the real MRRC book which shows the environment metaphor of a tissue culture laboratory. User will play a character as a lab assistant. User will see the laboratory layout, the virtual apparatus being used in the laboratory such as flasks, petri dish and test tubes. Users also can 'hold' those apparatus.
Activities &Task	Authentic activity	MRRC will provide real-life activities for a lab assistant. The application starts where the user receives and read instruction from a virtual memo to perform the tissue culture process (Fig. 4). Users can experience natural interaction with apparatus such as shaking the virtual test tube to separate the cells. Beside that, they can place the virtual petri dish on the palm to observe how cells proliferate (Fig. 6).
	Articulation	While using the system, lecturers can promote articulation such as asking probing questions to stimulate students. For example while users 'holding' a virtual mouse with engineered human ear as shown on Fig. 5, they can discuss what actually happened to that mouse.
Users	Collaboration	MR facilitates seamless/ natural face-to-face communication where two person will read the real books, see the monitor to view the virtual elements and can take turn to handle the markers. They can discuss on the content and also on the system. The real book serves as a focus for collaboration. When several users look at the same book page they can see the MR image from their own viewpoint. So collaboration can lead to articulation of strategies that can then be discussed, which in turn, will enhance generalizing grounded in students' understanding.

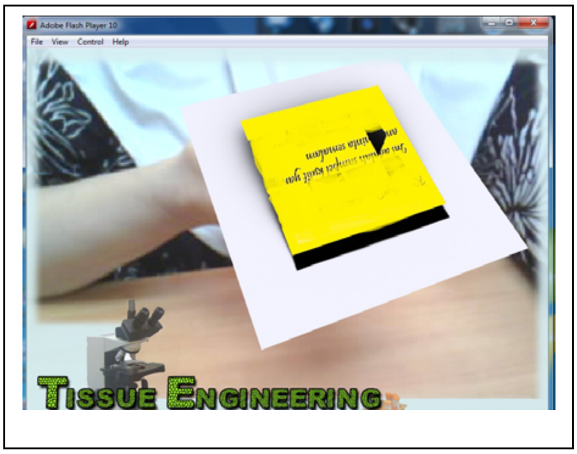

Fig. 4 User read a virtual memo

Fig. 5 User can examine an engineered mouse

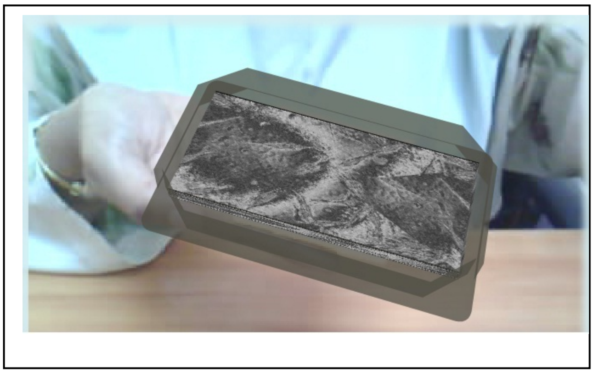

Fig. 6 User can hold the petri dish and observed cells proliferate

B. System Overview

The application developed using MR technology can be considered as a mirror metaphor [32] . A physical camera records what is taking place in front of the screen and projects this on the screen. The mirrored image of the physical image world is then augmented with the virtual environment. Fig. 7 shows the system configuration of MRRC.

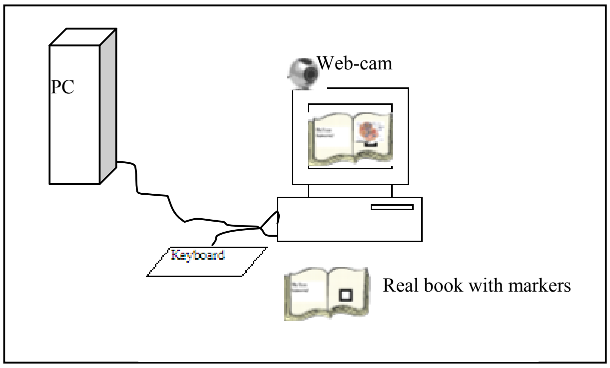

Fig. 7 System Configuration

Hardware

The main hardware components for MR are display, tracking, input device and computer.

- Display - Basically, there are three categories of displays for viewing the merged virtual and real environments: head worn, handheld, and projective [33]. To be cost effective, the display type of this application is monitor-based. It is perhaps the least difficult MR setup, as it eliminates HMD issues even though it is less immersive.
- Tracking - Tracking is the basic enabling technology for MR. Tracking is used to generate the merged real-virtual environment. The two most common tracking techniques used in MR applications include computer vision and external sensor system. This application uses real-time vision-based camera tracking technology that consists of web camera and two-dimensional fiducial marker system. All vision-based tracking methods are based on detecting and tracking certain features in images. Our tracking approach currently uses the corners of squares attached to a real book.
- Input device - An input device is used to manipulate the digital information displayed over the real environment. Input device for this application is web camera and fiducial marker system and also keyboard.
- Computer - The PC uses a 3.2GHz Pentium 4 processor, 2GB memory which runs on the Windows XP.

Software

For the development of the application, we divide the software by two categories : off-line software technologies and real-time software technologies [34]. The off-line software technologies include a number of tools that must be used in order to prepare the content used in the augmentation (i.e. virtual information) as well as MR environment. The off-line software are FLARToolKit, PaperVision3D, 3D Studio Max, Adobe Photoshop and SoundForge. The real-time software technologies consist of all the software libraries that have been integrated into a single application that comprises of MR interface. The main real-time software technologies will be the FLARManager that consists of FLARToolKit and PaperVision 3D and also Adobe Flash Player 10.

IV. CONCLUSION

Designing a virtual learning environment using new technology such as MR is challenging since it is hardly easy to find guidelines or frameworks on designing of MR systems as learning tools. By using the MR technology that can be used to create the sensation that virtual objects are present in the real world, this paper describes some characteristics of situated learning that can be considered when designing and developing the MR system. The main characteristics of situated learning that has been adopted for this case study are the authentic context and authentic activity. In this paper, we also discussed the system overview.

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