Mixed Reality Systems for Learning: A Pilot Study Understanding User Perceptions and Acceptance

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Abstract. This paper describes a pilot study to investigate participants' perceptions of usefulness and usability of our developed Plant Mixed Reality System (PMRS), designed for primary school children (11-12 years old). Preliminary results seemed to indicate participants' intention to use PMRS for learning. The paper concludes with a discussion on how the findings were used to formulate a second study based on the Technology Acceptance Model, and discuss implications on intention to use and acceptance of mixed reality systems for education.

1 Introduction

Mixed reality (MXR) is one of the newest technologies explored in edutainment that promises the potential to revolutionise learning and teaching, making learners' experience more "engaging", either through the incorporation of virtual objects into a real three-dimensional scene, or alternatively through the inclusion of real world elements into a virtual environment" [1].

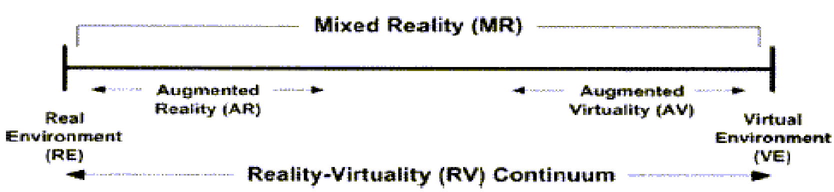

Fig. 1. Reality-Virtuality Continuum (Taken from [24])

MXR is a technology that falls under the wider set of technologies known as virtual reality (VR) or virtual environments (VE). A reality-virtuality continuum proposed by [13], illustrates real environment on one end and virtual environment on the other. In between, there may appear flavours of integration such as augmented

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reality (AR) and augmented virtuality (AV), depending on whether reality or virtuality was being enhanced (Figure 1).

2 Mixed Reality Projects in Education

In recent years, many MXR applications have been constructed for the learning of astronomy [2], oceanography [4], mathematics [26] and other topics [20]. These technologies are challenging conventional delivery modes in education.

In education, studies on the use of virtual reality (VR) or VEs have been conducted as early as in the 1990s. For example, Bricken and Byrne [3] carried out a summer camp where students aged 10 – 15 years used VR tools to construct and explore virtual worlds. The potential for such virtual technologies is high. Areas that they can be applied to are: formal education, informal education (such as museums), distance learning, vocational training and special needs education. Pan, Cheok, Yang, Zhu and Shi [16] document a number of VE learning projects such as a Magic story cube for storytelling and an interactive mixed reality Kyoto garden. These could be used in formal or informal education.

Woods et al (2004) set up several educational exhibits for Science centers, Museums etc. [25]. Stanton et al [21] collaborate with children and teachers together, design a tangible interface for storytelling. Education Arcade project [17], persons from MIT proposed a new concept “Games to Teach” and they developed three prototypes for electromagnetic, environment and history education. FlatWorld [15] created in USC can be used for education and training goals. Shelton et al [18] developed a system to teach Earth-Sun relationships to undergraduate geography students. It focuses on earth and sun related knowledge such as equinox, solstice to give students an AR experience.

Mathematics is another subject that could benefit from the use of VEs, as proposed by studies such as Pasqualotti and Freitas [17]. Three-dimensional environments enable users to explore spatial relationships, a key aspect in the teaching of geometry. Within the local context, Leow’s [11] dissertation study was conducted to explore the relationship between spatial ability and the learning of 3-D geometric objects using an AR prototype. The study seemed to suggest that AR could potentially be useful for students with lower spatial ability to learn 3D objects.

3 Case Study: Plant Mixed Reality System (PMRS)

MXR systems are expensive to design and develop. History has shown that as new technologies evolve before maturing and succeeding in penetration and acceptance in our daily lives, there is a need to carry out user studies to understand users’ perceptions of usability and usefulness of such technologies as early as possible to avoid expensive remedial work later.

However, to our knowledge, there is no well-accepted evaluation framework to understand students’ acceptance of the MXR technologies for learning. This paper attempts to use a well-established Technology Acceptance Model (TAM) [6] to investigate users’ intention to use. In this paper, we describe a pilot study, a precursor to a larger study using a modified TAM, in which a small group of participants gave feedback on perceptions of usefulness and usability of our developed Plant Mixed Reality System (PMRS).

PMRS, developed by the Mixed Reality Lab of the National University of Singapore (NUS), is selected as a case study to understand users' perceptions of MXR systems because this system is one of the first known educational MXR programs designed according to the local school syllabus and deployed in a local primary school (School X) in Singapore [14]. It was designed for Primary Five students (11-12 years old), who are taught seed germination, plant reproduction, seed dispersion and photosynthesis in their science lessons.

Most AR education prototypes are being developed to complement/enhance traditional teaching method and are not really classroom-based educational tools. John Dewey's theory [9] of education shows that children soak up knowledge and retain it for use when they are spontaneously induced to look into matters of compelling interest to themselves. As a science module, the experiment and direct experience are very important for students to grasp the knowledge. Many phenomena such as seed germination, photosynthesis, either need long times to happen or difficult to observe using naked eyes. For this reason, the mixed reality (MXR) technology was selected to develop an educational tool for the Plant System. We worked with a group of teachers from School X in Singapore to develop PMRS.

Based on the content from teachers and the real experiment, a system structure was designed. Physical objects were used in this project to give pupils the real experience.

As a classroom-based system, PMRS must be suitable for the classroom environment and at same time also suitable for self-learning. By projecting the display on a big screen, a teacher can use this system as a general teaching tool. For self-learning, texts and sounds were added in this system to help students to better comprehend the contents. In addition, the MXR technology also aims to bring the entertainment elements to the learning process, allowing pupils to learn in a more interesting way.

Unlike immersive VR, the PMRS interfaces allow users to see the real world at the same time as virtual imagery attached to real locations and objects. In a PMRS interface, the user views the world through a hand-held or head-mounted display (HMD), that is, either see-through or overlays of graphics on video of the surrounding environment. The most unique character of PMRS is that the interface allows students to interact with the real world in a tangible way. PMRS aims to provide a totally different learners' experience in education by:

- Supporting seamless interaction between real and virtual environments;
- Using a tangible interface metaphor for object manipulation; and
- Switching smoothly between reality and virtuality.

As shown in Figure 2, using physical spade, pupils can add virtual seed real flowerpots. They can also add virtual seeds using spade as well as add virtual water using watering can. By pressing a button, pupils can observe the seed germination process under different conditions.

Figure 3 shows germination and growth of a healthy bud with enough water, suitable temperature and light. Through observing and using PMRS, students can gain

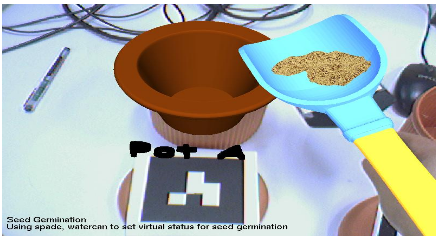

Fig. 2. Adding virtual soil in the flower pot

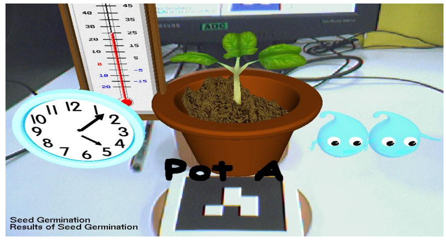

Fig. 3. A healthy bud germinated

knowledge about seed germination from their own experience under the teacher's instruction.

4 The Pilot Study

4.1 Aim

The pilot study, part of a bigger study to understand perceptions of users based on TAM, was carried out in June 7, 2006, over approximately two hours, in a laboratory. This study focused on a small group of student volunteers. It is difficult to bring children into the design process due to the assumptions and power structure imposed on them by adults [7]. The concept of children as design partners has been applied to cases such as Theng et al [22, 23]. In light of this, the involvement of primary school students in an informal and non-intimidating setting was used to gather the responses of this user group towards the PMRS.

4.2 Profiles of Subjects

A group of seven primary school students comprising three boys and four girls were recruited from another local primary school (School Y). These participants were in Primary Six (aged 11 – 12 years old), and had gone through the Primary Five science syllabus the previous year. They were put into 3 groups – Group A (2 girls named A-1 and A-2), Group B (2 girls named B-1 and B-2) and Group C (3 boys named C-1, C-2 and C-3). A group setting was used because this would reflect the real-life scenario in a primary school setting where students were required to work and learn together.

The participants interacted with the PMRS. The session was videotaped to capture the participants' reactions to the program, how they used it and how they interacted in a group. The room set-up involved a camera, a monitor, a board of markers (symbols), a keyboard, as well as cylinders and other objects with a marker card on them, as well as speakers.

4.3 Protocol

The session started off with a demonstration of the PMRS program by the Research Engineer. She explained the various modules and the use of the keys and cylinders to interact with the PMRS. This was followed by a brief hands-on session during which the students played around with the program in their groups A, B and C in order to get a feel of the program. After this, the actual task-oriented interaction session of the programs began. Each group was given some questions on the worksheet to answer in order to guide their interaction with the program, and then they were asked to complete a task. Upon completion of the interaction session, the students were asked to fill in the form to obtain their feedback on the PMRS.

Help was available during the session to answer questions or assist on the use of the system. After the interaction session, a brief focus group was conducted to discuss the participants' perceived usefulness and perceived ease of use of the PMRS. The focus group session was also videotaped. Two forms were used to collect data from the students. The first form was for gathering their responses that were specific to PMRS, namely their intention to use it, perceived usefulness and perceived ease of use, as well as the innovation factors and their attitude towards that particular science topic. The second form was for gathering information pertaining to the students themselves and their preferences on the accessibility and ability to collaborate.

5 Findings and Analysis

In this section, we begin with interaction summaries of participants with PMRS to understand usability and usefulness issues faced by the participants. The interaction summaries, transcribed from the video-taped accounts, are also coded, with negative comment or problem faced as [N#], and positive comment/observation as [P#].

5.1 Interaction Summaries

Group A. A-1 and A-2 took turns using the camera [P#1]. They had to observe the difference between a bisexual and a unisexual flower. Initially, they were unsure of what to look out for [N#1], but managed to obtain the answer after some prompting by the researcher. Next, they had to describe the cross-pollination process. With some guidance from the Research Engineer, A-1 used the cylinder to move the bee in the program to make it interact with the flowers.

Both A-1 and A-2 gave positive responses on their intention to use the program. A-1 commented that it would be more interesting to have this program [P#2] in her school and A-2 said, "I think my friends would like it [P#3]". Perceived usefulness was positive on all counts for both students. A-1 overall found the program easy to use [P#4] and said that she would need only some help with using it. In contrast, A-2 did not feel that it was easy to use and remarked, "Cannot see clearly and very difficult to operate [N#2]". Both students liked the program and the graphics [P#5]. A-2 found the bee cute [P#6]. A-1 liked this science topic [P#7], but A-2 did not [N#3].

Group B. The students observed from the program what happened when a plant did not disperse its seeds. They then had to interact with the cylinders to find out how different plants dispersed their seeds. B-2 was manipulating the camera and cylinders. B-2 also manipulated the plush monkey that represented the animated monkey in the program. She expressed the answers aloud as she interacted with the program, for example, “Wind”, “Splitting”, “That’s animal”. B-1’s interaction was more limited. During this Plant program session, she took down some of the answers and used the keys to move to other stages in the program. At the end, B-2 handed the camera to B-1 and completed the worksheet.

Intention to use and perceived usefulness were found to be positive by both students [P#8]. They both did not find the program easy to use [N#4], however, with B-2 citing that it was “hard to focus”. Although both liked the graphics [P#9], only B-2 said that she enjoyed using the program [P#10] while B-1 answered “Maybe” to that question. Both gave a “Maybe” to the question on whether they enjoyed being able to pick things up in the program and move them around. They both indicated that they liked this science topic [P#11]. B-2 remarked that the topic was very interesting [P#12]. Table 2 shows the positive and negative comments.

Group C. For their task, the students were required to experiment with “growing” a seedling. They began with C-2 holding a small physical plastic “watering can”, C-3 holding the camera and C-1 holding a physical plastic “spade”. C-2 then took over the camera. With guidance from the Research Engineer, C-2 and C-1 took turns in “scooping” the virtual seeds into the virtual pot with the spade and watering it. C-3 took over the camera again. They “added” sunlight and water to the pot and observed the germination of the seeds. The three participants took turns to use the PMRS and helped each other with the system [P#13]

Intention to use and perceived usefulness of the program were positive for all three students [P#14]. With respect to perceived usefulness, C-2 commented, “The ability to interact with the program and its 3D graphics make using this program fun [P#15]”. Perceived ease of use was overall positive, although C-1 and C-2 said that the use of the cylinders was not easy [N#5]. Regarding this point, C-2 found that “the camera was too sensitive [N#6]”. The three students enjoyed the program [P#16]. They also liked the graphics, with the exception of C-2, who noted, “Sometimes, part of the graphics disappear [N#7]”. C-3 commented that the graphics were “almost better than my computer”. All three students liked this science topic.

5.2 Focus Group Feedback

The focus group session was held after the participants used the PMRS. The comments made during the focus group concurred with the comments and observations made (see Table 1’s summary of the positive comments/observations and negative comments made).

When asked to express what they liked about the program, several students mentioned the monkey. They felt that it was cute. There was also a comment that they liked the program because it was 3D. A student from Group A opined that the Plant program was more fun and less complex. With regard to usefulness, the students said that it could help them recall what they had learnt in their lessons and that it was useful for revision. There was a general preference towards independent exploration, rather than having a teacher using it for demonstration purposes.

In terms of usability, issues were raised regarding the manipulation of the various devices, that is, the camera, the cylinder and the keys. Students brought up the difficulty of positioning the camera properly, citing it as being “hard to focus”. They also mentioned that graphics would “disappear”, referring to the times during the interaction session when the graphic displayed on the monitor would keep flashing (vanish momentarily) due to hardware and software rendering issues. The graphics would vanish very briefly, perhaps for milliseconds, however, this was perceptible and disrupted continuity. With regard to the issue of the cylinder, there was some perceived lack of sensitivity in obtaining the response from the program. For the keys, they were not intuitive to the students, who experienced difficulty in the navigation. When asked to suggest improvements, one student offered the idea of having a fixed camera to enable a wider field of view. There was also a suggestion to use bigger and clearer fonts for the text, as well as to have the text face the camera.

Overall, it was seen that usability was a major issue for the students. However, they perceived the program to be useful and could conceive of other topics that the program could be useful for, such as Maths/Chemistry/Biology. They also showed a preference for independent exploration, which could indicate high self-efficacy and personal innovativeness.

Table 1. Positive and Negative Observations and Feedback on PMRS

Activities	*Positive Comments*	*Negative Comments*
Observation	1. Cooperation among students in using the program – took turns in using camera [P#1, 13]	2. Unsure of what to observe in the program [N#1].
Feedback	1. More interesting than the traditional classroom lesson [P#2, 7, 11, 12] 2. Perceived usefulness and positive intention to use program [P#4, 8, 13, 14] 3. Perception of peer acceptance of program [P#3] 4. “Cute” graphics [P#5, 6, 9] 5. Enjoyed using the PMRS [P#10] 6. Enjoyed using PMRS because of interactivity and 3-D graphics [P#10, 16]. 7. Fun to use [P#15].	8. Experienced difficulty in use [N#2, 4]. 9. Did not like the topic selected [N#3] 10. Cylinder was not easy to use [N#5]. 11. Camera was too sensitive [N#6]. 12. Disliked the momentary “disappearances” of the graphics [N#7]

6 Factors Affecting Perceptions and Acceptance

In this pilot study, we observed comments made by the participants indicating important factors leading to intention to use the PMRS. It would seem that the innovation factors explored might have to be compatibility with needs, values and past experiences, perceived enjoyment, perceived system quality and interactivity. For individual factors, perhaps gender, personal innovativeness and self-efficacy need to be selected. Another factor such as the environmental factor, that is the ability to collaborate, could also used. Some studies have suggested that children like to work and learn together and that group dynamics may play a role in their attitude towards the activity (e.g. [5], [8], etc.), thus, their attitude towards the ability to collaborate when using the programs could also be explored.

To get statistically-evidenced findings, we require a bigger sample of participants to investigate students' perception and acceptance of MXR systems for learning. To design the second study, we examined a number of theories developed to understand the adoption and diffusion of IT-based innovations. Among the key theories, the Technology Acceptance Model [6] has "emerged as the theory of choice", with many studies (424 journal articles as at January 2000) citing the original TAM research paper [6]. It has been proven to be a simple and yet powerful model in predicting acceptance.

Based on findings (that is, feedback given as shown in Table 1) from the pilot study and other studies (e.g. [1], etc.), the following factors selected for the second study were:

- *Perceived enjoyment:* This is defined as the "extent to which the activity of using a specific system is perceived to be enjoyable in its own right, aside from any performance consequences" (see Table 1, Feedback #5-7).
- *Cognitive absorption:* This construct is defined as "a state of deep involvement with software" that consists of five dimensions, namely temporal dissociation, focused immersion, heightened enjoyment, control and curiosity " (see Table 1, Feedback #4-6).
- *System quality:* This is known as "perception on how well the system performs tasks that match with job goals", thus quality can refer to quality of output or information produced by the system " (see Table 1, Feedback #8-12).
- *Personal innovativeness:* This refers to "the willingness of an individual to try out any new information technology" " (see Table 1, Feedback #1).
- *Compatibility:* This is the "degree to which an innovation is perceived as being consistent with the existing values, needs, and past experiences of potential adopters" " (see Table 1, Feedback #1).
- *Self-efficacy:* This is "the belief that one has the capability to perform a particular behaviour". " (see Table 1, Feedback #2).
- *Social influence:* This is a "person's perception that most people who are important to him think he should or should not perform the behaviour in question". " (see Table 1, Feedback #3).

7 Conclusion and Future Work

In recent years, more user studies were being carried out on MXR systems. For example, Mikropoulos, Chalkidis, Katsikis, and Emvalotis (1998) [12] investigated the attitudes of students towards educational virtual environments and the peripheral devices. In a more recent example, Shin [19] conducted a user study for an educational VR system for earth science. It was very specific to the system and did not employ any formal evaluation model.

This paper describes a pilot study in an attempt to investigate participants' perceptions of usefulness and usability of our developed PMRS, designed for primary school children (11-12 years old). Preliminary results seemed to indicate participants' intention to use PMRS for learning. However, it is possible that overall positive impression of anything high-tech could affect users' responses. Hence, long-term effects should be investigated, that is, whether experience can affect people's attitudes and behavioural intention towards such systems. Users' criteria for evaluation could evolve as they become more familiar with such technology. For example, they may demand more sophisticated graphics and more novel and varied ways of interacting with the system.

Based on findings from this pilot study, we formulated a second study based on the Technology Acceptance Model, and discuss the probable constructs/factors that are important to investigate intention to use and acceptance of MXR systems for education.

Future work includes carrying out the second study on the PMRS using a modified TAM, with more students and teachers performing different tasks.

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