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Evaluation of learners' attitude toward learning in ARIES augmented reality environments

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ABSTRACT

The ARIES system for creating and presenting 3D image-based augmented reality learning environments is presented. To evaluate the attitude of learners toward learning in ARIES augmented reality environments, a questionnaire was designed based on Technology Acceptance Model (TAM) enhanced with perceived enjoyment and interface style constructs. For empirical study, a scenario of a chemistry experimental lesson was developed. The study involved students of the second grade of lower secondary school. As follows from this study, perceived usefulness and enjoyment had a comparable effect on the attitude toward using augmented reality environments. However, perceived enjoyment played a dominant role in determining the actual intention to use them. The interface style based on physical markers had significant impact on perceived ease of use. Interface style and perceived ease of use had a weak influence on perceived enjoyment. In contrast, these two constructs had a significantly stronger influence on perceived usefulness.

1. Introduction

The two most important social and economic processes occurring nowadays are: emerging electronic knowledge-based economy and transformation toward global information society. Therefore, creativity and innovation become more and more prominent determinants of the competitiveness on the labor market in the 21st century. This is a major challenge for education and teaching that needs to be addressed in the near future (Cellary, 2002). The aforementioned challenges require significant improvement of teaching methods, which will transform the role of learners from passive recipients of information to active participants in knowledge acquisition (Walczak, Wojciechowski, & Cellary, 2006).

In response to this need, an increasing interest in teaching based on the constructivist learning theory has taken place since the 90s of the 20th century (Wilson, 1996; Jonassen, 1999; Marshall, 1996). There are a wide variety of perspectives on what the term *constructivism* means (Piaget, 1973; Vygotsky, 1978; Bruner, 1996). In this paper, the constructivist learning is understood as an active process of constructing knowledge by the learner, in contrast to passive acquiring the information (Duffy & Cunningham, 1996).

According to the constructivist approach, a teacher is a facilitator of learning rather than a transmitter of knowledge (Chaille & Britain, 2002). There are a number of possible pedagogic activities implementing the constructivist principles, such as experimentation, conducting discussions, performing projects, etc. All these activities encourage learners to be active and to make their own discoveries, inferences, and conclusions. Deployment of constructivist principles in a classroom requires usage of interactive and dynamic learning environments, where the learners are able to modify appropriate elements, test ideas, and perform experiments (Roussou, 2004).

Learning based on performing experiments and further reflection on their results is the basis of the *learning-by-doing* paradigm (Schank, Berman, & Macperson, 1999). This paradigm implies that the best and the most natural way of learning how to do something is trying to do it. A learning strategy that implements the learning-by-doing approach is *experiential learning* (Kolb, 1984; Beard & Wilson, 2006). This strategy greatly increases understanding and retention of the learned material in comparison to the methods that solely involve listening, reading, or even viewing, as learners are usually intrinsically motivated to learn when they are actively engaged in the learning process (Yang, 2012).

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A key determinant of the effectiveness of experiential learning is interactivity (Roussou, 2004). As far as learning content is concerned, the interactivity is defined as: "the extent to which users can participate in modifying the form and content of a mediated environment in real time" (Steuer, 1992, p. 14). In traditional learning, the highest level of interactivity can be achieved in teaching labs, where students are able to conduct experiments putting theoretical concepts into practice. However, there are serious limitations associated with the experiments performed in teaching labs, since they may require much space, expensive equipment, appropriate safety measures, and trained staff. These restrictions make the large scale dissemination of experiential learning in educational institutions practically impossible or economically unjustifiable (Jara, Candelas, Puente, & Torres, 2011). Without breaking down those barriers, experiential learning will remain of more theoretical rather than practical significance.

In this paper, we consider application of image-based *augmented reality* (AR), which is an extension of *virtual reality* (VR), to create learning environments enabling experiential learning. Virtual reality is defined as "a high-end user–computer interface that involves real time simulation and interactions through multiple sensorial channels. These sensorial modalities are visual, auditory, tactile, smell, and taste" (Burdea & Coiffet, 2003, p. 3). In this paper, we focus on two essential aspects of VR, namely three-dimensional (3D) visualization and interactivity. Such a VR interface is called a *virtual environment* (VE), which is a 3D digital model of a real, abstract, or imagined environment. Virtual environments potentially offer a much broader range of forms of interactivity than real environments. Users are able to freely navigate in a virtual environment, observe the environment from different perspectives, and interact with selected virtual objects. Virtual environments can be used to implement *virtual laboratories* in which users are able to perform experiments (Dalgarno, Bishop, Adlong, & Bedgood, 2009; Jeong, Park, Kim, Oh, & Yoo, 2011). However, to create a virtual environment offering a high level of credibility it is required to create a 3D model of an entire real environment, which is both time-consuming and expensive. The current state of the VR technology causes the separation of humans from the real world, requires the use of expensive equipment to display and manipulate virtual objects, and also offers an indirect non-intuitive user interface.

In comparison to virtual reality, which is aimed at immersing a user in a synthetic environment, augmented reality supplements the user's perception of the real world by the addition of computer-generated content registered to real-world locations (Azuma, 1997). Augmented reality combines virtual reality with video processing and computer vision technologies (Parker, 1997; Davies, 2005). The AR technology enable merging virtual objects with the view of real objects, resulting in *augmented reality environments*. In augmented reality environments both virtual and real objects can co-exist and interact in real time (Milgram & Kishino, 1994).

The creation of AR environments requires design of virtual representation of a relatively small part of these environments. A significant part of AR environments consist of real objects, for which it is not necessary to create detailed 3D models, while offering the highest possible level of reality. In AR environments, users are able to interact with virtual objects in a direct and natural way by manipulating real objects without the need of sophisticated and expensive input devices (Wojciechowski, Walczak, White, & Cellary, 2004). Also, in contrast to virtual environments, in which users communicate in a mediated way via avatars, AR environments afford users direct face-to-face contact with each other.

AR environments offer better opportunity of learning-by-doing through physical movements in rich sensory spatial contexts (Dunleavy, Dede, & Mitchell, 2009). Therefore, users have an opportunity to perform experiments on virtual objects by hands-on experiences in their real environments. This feature of AR supports *situated learning* which means that learning should take place in the context in which it is going to be applied (Lave & Wenger, 1991). AR allows students to seamlessly combine learning environments with the real world in which they live and apply the knowledge and skills learned. AR environments with possible direct face-to-face interaction between learners foster the creation of *communities of practice* focused on the goal of gaining knowledge related to the presented content, since the learners are able to easily share gained information and experiences with the group (Lave & Wenger, 1991).

The main advantages of AR applications in the education domain are: activity of learners, cost and safety. AR environments allow learning content to be presented in meaningful and concrete ways including training of practical skills. They may play active roles in a wide range of learning activities within interactive educational scenarios developed in accordance with the learning-by-doing paradigm. The experience gained by learners during the learning process within an AR environment can be the basis for reflection and further group discussion in a classroom. The main aspects of learning afforded by AR environments are: spatial ability, practical skills, conceptual understanding, and inquiry-based activities (Cheng & Tsai, 2012).

Application of AR environments for teaching is followed by cost reduction due to replacing real expensive resources, such as laboratory equipment and supplies, with their virtual counterparts. A significant advantage of AR environments is safety, since unskilled learners may explore potentially dangerous situations without any risk of harm to themselves or damage to expensive equipment.

There are a number of possible applications of AR environments in education (Walczak et al., 2006). They can be used for teaching about objects and phenomena impossible to see by naked eye (e.g., molecular movements), simulation of potentially dangerous situations (e.g., chemical reactions), and visualization of abstract concepts (e.g., magnetic fields). In addition, the level of complexity of the presented phenomena can be reduced to allow the learners to easier gain knowledge about the underlying concepts. AR environments may be used in a wide spectrum of domains from natural sciences (e.g., chemistry, physics, biology, astronomy), through computer and information sciences, mathematics, engineering (e.g., mechanical, electrical, biomedical), to humanities (e.g., history, linguistics, anthropology).

This paper is organized as follows. In Section 2, basic concepts related to augmented reality environments are introduced, as well as an overview of applications of AR in education. In Section 3, an overview of the ARIES system is presented. In Section 4, the TAM-based research model and an application scenario of the ARIES system are described. This section also contains a description of the research study. In Section 5, the results of the system evaluation are presented. Finally, Section 6 concludes the paper.

2. Augmented reality in education

2.1. Categories of augmented reality environments

Augmented reality is a broad concept, which applies to "technologies that combine the real and the virtual in any location-specific way, where both real and virtual information play significant roles" (Klopfer, 2008, p. 92). In general, AR systems are divided into location-based and image-based systems (Cheng & Tsai, 2012).