Game-Based Learning: Augmented Reality in the Teaching of Geometric Solids

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ABSTRACT

In teaching, the use of virtual and augmented reality has been on the rise, exploring different means of interaction and student engagement. Based on constructivist pedagogic principles, augmented reality pretends to provide the learner/user with effective access to information through real-time immersive experiences. Game-based learning is one of the approaches that have received growing interest. This paper presents the development of a game in a teaching and learning context, aiming to help students acquire knowledge in the field of geometry. The game was intended to develop the following competences in primary school learners (8-10 years): a better visualization of geometric objects on a plane and in space; understanding of the properties of geometric solids; and familiarization with the vocabulary of geometry. The authors will show that by using the game students have improved around 35% the hits of correct responses to the classification and differentiation between edge, vertex and face in 3D solids.

Keywords: Augmented Reality, Design Thinking, Educational Technology, Game-Based Learning (GBL), Game Design, Gamification, Geometry

INTRODUCTION

Digital technologies have been growing in diversity and the possibilities they offer have increased, providing new opportunities for the transmission of knowledge. Evidence that computer games have rapidly become a dominant entertainment is found in the sales volume, in usage statistics and in public opinion polls (Gartner, 2011). In education, too, digital games represent a learning method which has gained much popularity and interest (Bie & Lipman, 2012). However, van Eck (2006) alerts teachers to the danger that, by turning everything into a game, they might diminish the pleasure associated with play. This was evidenced by experiments with educational software platforms over the past decades which, instead of taking advantage of the power of games to transfer knowledge, have developed boring games which prejudice learning.

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Constructivism supports the concept of active learning experiences which allow the learner to connect him/herself directly to knowledge in order to create new knowledge and thereby improve their reasoning and problem-solving abilities (Huang et al., 2010). In this sense, digital educational games can be efficient and engaging because knowledge is constructed through the learner’s activity and interaction with the environment in a continuous and active process in response to external stimuli. Digital games are currently a hotly debated topic, with both defenders and opponents being equally inflexible and emotionally involved in relation to their opinions. According to Barrett and Long (2012), misunderstandings exist on both sides of the debate and terminology and attribution abuses are numerous.

Multimedia and human-computer interfaces are constantly bringing new challenges, leading to the development of new tools which encourage a more collaborative and engaging type of learning and, therefore, learners’ active participation in the construction of knowledge. In this context, augmented reality (AR) offers functionalities which improve immersion, interaction and imagination, experiences particular to the constructivist principles of learning. However, despite technology’s important role in integrating learners in the field of experience (Oblinger et al., 2005), it represents merely a means to an end. Games are efficient not for what they are in themselves, but for what they contain and for what students achieve while playing.

In this relationship with practice, this paper contemplates the development of a game to be used in the teaching of primary-school geometry, whose main purpose is to develop learners’ spatial sense, with emphasis on visualization. Usually, primary-school learners experience difficulty in developing and consolidating their spatial sense, namely the visualization and the understanding of the properties of geometric figures on a plane and in space. They also present difficulties in acquiring the vocabulary associated to geometrical concepts such as face, edge, vertex, plane, prism, pyramid, cylinder, cone, sphere, among others.

There are several examples on the integration of education, games and AR. Kaufmann (2004) presented Construct3D, a major project which resulted in a geometric construction tool especially designed for the teaching of mathematics and geometry in secondary and tertiary education. It allows the visualization of three-dimensional (3D) objects which so far had to be calculated and constructed by means of traditional methods. AR is used as a way of improving interfaces for a future generation, allowing students to work directly in a 3D space. Morais et al. (2008) presented GeoEspaçoPEC, which fits in a context of educational games whose objective is to stimulate learners to spatial geometry knowledge. It was developed to focus on fundamental contents in plane geometry. It is structured as a Role Playing Game (RPG) which, through the exploration of solutions and answers, allows the learner to move from one level to the next and thus acquire spatial geometry knowledge at each new level. Not related with geometry, Medicherla et al. (2010) presented a project in which an interactive solar system was developed to help middle school students in the sciences understand spatial concepts using AR. In 2011 an overview for AR in education was presented by Yuen et al. (2011). Silva and Silveira (2012) presented ARGeometric, an educational tool in the field of geometry which proposes a game development methodology. It consists of a fixed board with holes shaped as geometric forms (a circle, triangle, or square) in which, with the help of AR markers, the pupil tries to fit geometric solids. Lim et al. (2012) present a system that consists of an authoring tool that can be used to create educational contents, a viewer that plays those contents and an engine to power the tool and viewer. Lin et al. (2013) present a study that integrates AR technology into teaching activities to design a learning system that assists junior high-school students in learning solid geometry. Furió et al. (2013) studied the effects of the size and weight of a mobile device on an educational game, and their results show that the different characteristics (screen size and weight) of the devices did not influence the children’s acquired
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