

Abstract

Augmented Reality (AR) is a technology that has boomed in the last few years especially in mobile devices. It is in mobile devices in which the hardware and software that are now available present the greatest advances over their predecessors. These advances currently make it possible to run AR applications on mobile devices without problems. The main objective of this thesis is the development and validation of mobile educational games for children. The developed games combine m-learning, edutainment and AR.

M-learning is a learning methodology that uses mobile devices. Teaching through m-learning has some advantages over traditional teaching (i.e., the capability to continue to learn outside of educational environments). Edutainment refers to the content created to educate and entertain at the same time. AR consists in merging real images with virtual objects.

The games that were developed include mini-games with and without AR. Physical manipulation (tangible), keyboards or tactile screens, and accelerometers are used for the interaction. In the studies carried out, the games are compared with traditional games/teaching and other devices (Tablet PC) in order to observe the efficacy that these games have regarding the acquired knowledge, engagement, ease of use, and their influence on children. The Nokia N95 8Gb and the iPhone 3GS have been used as mobile devices. These devices have the minimum requirements for developing AR games (a camera, graphics acceleration, etc.). In addition, the iPhone has a tactile screen and an accelerometer, which allow for more complete and varied interactions.

Three mobile educational games for children ranging in age between 8 and 13 years old have been developed. ARGreenet, which was developed for the Nokia N95 8Gb, aims to raise children's awareness of climate change and how they can reduce their environmental footprint by recycling. Two games were developed for the iPhone. The first one is a game about multiculturalism in which children learn about the food, monuments, and typical animals of the

poorest continents in the world. The second game is about the water cycle.

A total of six studies were carried out to determine the efficacy of the games with regard to learning, ease of use, engagement and fun, satisfaction, and the influence they have on children. In the first study, the AR version (ARGreenet) was compared to a non-AR version (BasicGreenet). In the second study, an individual version of ARGreenet was compared to a collaborative version of the same game (TeamARGreenet). In the third study, three ARGreenet versions were compared: an individual, a collaborative, and a competitive version. The results of these three studies showed that ARGreenet influences the children in a way similar to the non-AR version and that there are no significant statistical differences among the different versions of ARGreenet. Despite this fact, the children preferred ARGreenet over BasicGreenet, and preferred the competitive version over the individual and the collaborative versions.

In the fourth study, the game about multiculturalism was compared to traditional games. The results showed that the children acquired similar knowledge with both the traditional and the iPhone games. Also, a great majority indicated that they preferred the iPhone game over the traditional games and that they would like to play the game again. The children achieved similar knowledge improvements using both the autonomous game (iPhone game) and the custom, guided game (traditional games).

In the fifth study, the game about the water cycle was analyzed using two different mobile devices: an iPhone and a Tablet PC. From the results, it can be observed that the different features of the devices (size of the screen and weight) did not influence the children with regard to the acquired knowledge. In the sixth study, the game about the water cycle was compared to a traditional lesson. From the results, it can be observed that the game proved to be as effective as the traditional lesson regarding the acquired knowledge. However, the iPhone game also achieved a greater motivational effect on the children.

The following general conclusions have been extracted from the studies carried out:

- Mobile devices possess the appropriate features (camera, tactile screen, accelerometer, GPS) to help in the learning process.
- The inclusion of AR in the game allows the children to explore what they are learning from different perspectives in an easy and intuitive way.
- Most children would like to use AR in a classroom as a learning tool.
- Mobile educational games are effective in transmitting knowledge.

- The type of game developed makes versatility in the learning process easier to achieve, since, children can learn anywhere at any time with a mobile device without requiring supervision. Therefore, these games can be used as a complement to traditional lessons.
- The use of mobile devices with different physical features (size of the screen and weight) does not significantly influence the knowledge acquired. Nevertheless, they are aspects to be considered when taking the age of the participants into account.