Lessons learnt from an experience with an augmented reality iPhone learning game

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ABSTRACT

In this paper, we present an augmented reality (AR) iPhone game for learning multiculturalism and solidarity. The subject was chosen based on a study in which participated 150 professionals. The game was designed following different design principles. The game includes several interaction forms (physical manipulation, touch-screen and accelerometer interaction). Eighty-four children from 8 to 10 years old participated in a study for checking different aspects of the game. In this paper, four of these aspects are presented: the easiness of use, the preferred interaction method, the predisposition of using AR at school for learning, and the preference about the game. From the results, 49% of participants considered that the AR device was extremely easy to play with. For interaction, the children preferred the use of the accelerometer (39%), followed by the use of AR (27%) and the tactile screen (27%). The majority of participants (91%) appreciated the possibility of incorporating AR in their learning activities at school, and 81% of the participants preferred the experience offered by the AR game over the traditional game. Finally, based on this experience, we refine several design principles for mobile AR learning games for children.

Categories and Subject Descriptors

H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities

General Terms

Experimentation.

Keywords

augmented reality, learning, edutainment, iPhone.

1. INTRODUCTION

Since learning is a very important process, new methodologies and tools are frequently studied and evaluated for their introduction and use in the classroom. Play and learning are closely related, and this link can be used to learn by playing. Nowadays, in educators' minds, there is no doubt that children can enrich and complement their skills through play.

One of the objectives of our work was to determine the content preferences of most gaming/pedagogical interests for the Spanish primary school collective (6-12 years old). To determine these preferences, a study of preferences about subjects of interest for children was carried out. The experience of the authors indicates that an adequate approach for the selected subject can vary substantially the success of the game. In this study, participated 150 experts in education and teachers, 68% males, 32% females. One of the questions that these professionals answered was:

- Please, indicate 4 subjects that you would like to be included in an AR learning game: 1) nature and living organisms; 2) science and technology; 3) road rules; 4) sport and outdoor activities; 5) health and hygiene; 6) moral and ethical values; 7) multiculturalism, solidarity and tolerance; 8) calculation and reasoning; 9) music; 10) history; 11) language and understanding; 12) other (specify).

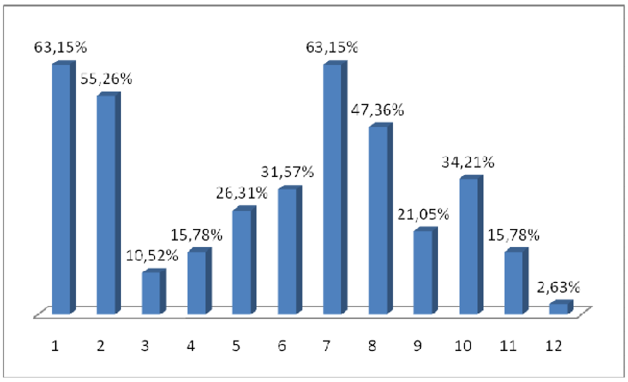

Figure. 1. Study of preferences. The meaning of the numbers in abscissa is explained in the text.

Analyzing the answers for this question (Figure 1) and considering that each participant chose 4 subjects, 63% chose 7) 'multiculturalism, solidarity and tolerance' and 63% chose 1) 'nature and living organisms'. Therefore, these two subjects are the preferences for learning using AR. We chose multiculturalism and solidarity for our game because it was one of the preferences and because it was also the theme chosen by the Summer School of the UPV where the game was going to be tested. This Summer School chooses a theme each year and it can coincide or not with the international theme of the year, but several years it is the same. After this selection, an AR game proposal for learning multiculturalism and solidarity was designed. In this paper, we present how this game was designed, a general description of the game, the results for several questions included in the study and the lessons learnt from this experience.

The objectives of our work, apart from determining the content preferences, were:

1) To design the most appropriate game to learn the selected content.
2) To try to incorporate as many interaction methods as possible.
3) To analyze different aspect of the game: easiness, preference of interaction method, learning outcomes, etc.

To achieve the objective of designing the most appropriate game, one area was to get the best possible interaction by choosing at each step of the game the most appropriate interaction (e.g. touch-screen or accelerometer). Good interaction is one of the most important factors that influence a gaming experience [1]. To achieve the second objective, several interaction forms were considered (physical manipulation, touch-screen interaction, etc.). Therefore, for these two objectives, we took into account previous studies that have provided several design principles and suggestions for mobile learning [2] and also for AR applications [1].

2. PREVIOUS WORK

Several AR applications have been presented for learning that use desktop computers. As the focus of this paper are handheld devices, only four quite different applications for PCs are cited. Construct3D [3] was an AR system for constructing 3D geometries that was designed to teach mathematics and geometry. It was tested with 14 students from two high schools in Vienna. The results from two evaluations showed that Construct3D encouraged learners to explore geometry. Larsen et al. [4] presented an AR system for learning how to play billiards. The most outstanding characteristic of this system was that the game was played on a real billiard table. Organic chemistry can also be taught using AR (Fjeld et al. [5]). In Fjeld's system, users interacted directly with 3D molecular models. In one of our previous work, Juan et al. [6], children used an AR game for learning the interior of the human body. Forty children took part in the study. They majority of participant would like to use AR for learning more about the human body and also for other subjects. In another work, Juan et al. [7], the children used an AR game for finding matching pairs to learn about endangered animals. Thirty-one children participated in the study in which the AR game was compared with a real game. The majority of participants preferred the experience offered by the AR game over the traditional game. The children considered the AR game easy to use (5.74 ±1.63, on an scale from 1 to 7), but not so easy to use as the real game (6.77±0.5). For the same subject, but using another type of interaction, in Juan et al. [8] children used magnet cubes for interaction. Forty-six children played the AR game and the equivalent real game. The results indicated that children enjoyed playing the AR game. They also preferred the AR game to the real one.

For handheld devices, several AR applications have also been presented for learning. In 2007, Li et al. [9] developed an AR system for learning English called HELLO based on 2D barcodes. A four-week pilot study was conducted and the results indicated that 2D barcodes and AR were useful for English learning. In 2009, Wang et al. [10] tested three user interface prototypes for learning heritage temples. Their study showed that users preferred animated and interactive virtual elements with sound effects, and that the superimposed information should not cover more than 30% of the screen. In the same year, Alien Contact! [11] was presented. It was the first game developed in the Handheld Augmented Reality Project (HARP), http://isites.harvard.edu /harp. In Alien Contact!, participants use GPS-enabled handheld computing units. Alien Contact! is based on a scenario where aliens have crash landed. Students work in teams and learn math and literacy skills. In 2011, Juan et al. [12] presented an AR mobile phone game for learning how to recycle. They compared the AR mobile game with a videogame. 69.4% of the participants preferred the AR game, which they perceived as easy to use and more engaging and fun than the videogame.

Applications that run on the iPhone have also been presented; for example, Karpischek et al. [13] presented an AR application for identifying mountains. The application uses the iPhone GPS to get the location, digital compass, and accelerometer to get the orientation, and it uses web services to display what is visible from the user's point of view. Koh et al. [1] developed an AR cooking game. There are also several AR iPhone games that can be downloaded from the Apple Store, e.g. ARSoccer, ARBasketball Lite, Mosquitoes, or Pandemia.

Previous works allow us to identify that handheld devices had been less used than PCs for AR, especially for learning. When we started our research, the iPhone was not previously tested for learning. The iPhone incorporates different interaction forms that can be exploited in learning applications. Moreover, previous works that used handheld devices did not perform exhaustive evaluations.

3. GAME

3.1 General description

For the design of the iPhone game, we have considered all the design principles cited in the introduction section. These design principles for AR applications can be summed up as follow:

1) AR can use several input channels. It is suggested to combine these different input channels [14].
2) A mobile phone with a built-in camera is an interaction device with 6 Degrees of Freedom (DOF) [15]. It is possible to use this device as a tracking device.
3) For mobile AR user interfaces, it is suggested to consider the additional DOF that are available on the mobile phone respect to desktop metaphors [16].
4) For fiducial marker tracking in mobile AR applications, it is suggested to consider tangible AR techniques [17]. The interaction could be more natural and intuitive.

5) Creation of appropriate interaction techniques for AR applications that are as intuitive as possible [18].

We have also incorporated various forms of input methods such as AR marker tracking, physical manipulation, GUI interaction, standard I/O interaction, touch-screen interaction and the accelerometer.

The subject of the game is multiculturalism and solidarity. For covering the solidarity aspect, the mission of the game is to collect food from poorest continents such as Africa, Asia, and Central and South America. To cover the multiculturalism, while playing the players learn about food, animals, monuments, and meteorological phenomena typical from these continents. Using AR, the players explore a room searching for the objects requested by the guide character. Ten different AR markers were used and distributed in the activity room. When the requested object is food and it is found using AR, the game takes the player to the typical place to collect the food using a minigame. This is a smooth change because the learning context is the same. The children are still learning about the food. As they have to collect the food would be easier to remember it. The minigames are videogames without AR. In this particular step of the game, the iPhone serves as both as provider of an augmented point of view (when the player is looking for the objects in the room) and also to take the player to the place where the food has to be collected. This shift from an external perspective to an embedded agent in the game, allows the player to become part of the game and this can create more engaging player's experiences [19]. Using this shift, we have implemented a Continuous Natural User Interface. The minigames do not use AR, but they use the tactile capabilities (e.g. Figure 2). For example, the minigame of Figure 2 is to harvest peanuts. Peanuts are one of the food that children have to find in Africa. The children have to harvest as many peanuts as possible using the tactile capabilities of the iPhone, and placing the peanuts into the net. One of the minigames uses the built-in accelerometer that consists of a labyrinth where the players have to harvest potatoes that are distributed along it (Figure 3). The players are represented by a ball. They have to turn the iPhone in order to move the ball through the labyrinth and pick the potatoes in the time required. This minigame appears when the children are visiting Central and South America and find the Kukulkan temple. Related to the animals, Figure 4 shows an example. In this case, a dromedary was found. Dromedaries are one of the animals to find in Africa. One more example is depicts in Figure 5. This Figure 5 shows two objects that have to be found in the game, the Taj Mahal (Asia) and a giraffe (Africa).

In order to familiarize the children with the game and its different ways of interaction, first, they follow a tutorial. In this tutorial a friendly pet performs the introduction and she also guides them during the game (Figure 6). The game can be divided into two main parts: tutorial + game itself (with three continents). Therefore, the children follow the tutorial first and then visit the first continent where they have to undertake the task that has been entrusted to them. The order in which the continents are visited is: first Africa, then Asia, and then Central and South America. To avoid distracting the players, only the necessary information in each mission is presented [20]. Since the iPhone was used by children and to avoid damages, it was protected (e.g. Figure 2).

In the study conducted, the AR game was compared with traditional games. We designed several traditional games so that the children received the same information as in the AR game. A person explained the games and gave the same information that was included in the AR game. For example, Figure 7 shows two children that are manipulating one of the typical food from Asia, the rice. In this case, they have to manipulate real rice using a bowl full with normal rice (white rice). In this bowl, we put 4 grains that were painted black. The children have to look for these four black rice grains.

Figure 2. Minigame to harvest peanuts.

Figure 3. A girl is playing with the labyrinth minigame.

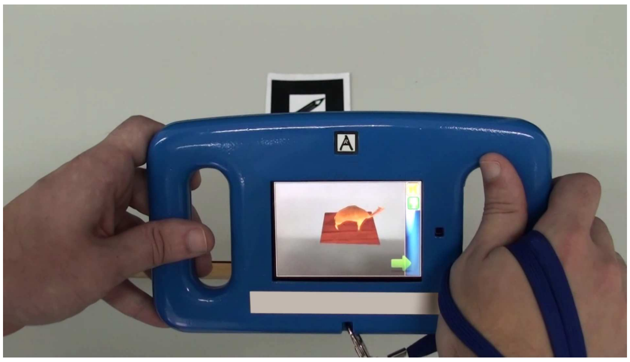

Figure 4. A dromedary has been found.

Figure 5. Screenshot of the iPhone game. The Taj Mahal and a giraffe are shown.

Figure 6. Patty (the friendly pet) is explaining the game.

Figure 7. Traditional game. Two children are looking for four black rice grains in a bowl full of white rice grains.

3.2 Technical characteristics

The technical requirements to develop and run the game on the iPhone were: 1) The Xcode 3 IDE and the iPhone SDK 3. The version used in this work was Xcode 3.2.2 with the iPhone SDK 3.2. 2) An iPhone 3GS with the operative system iOS 3. The version of the iPhone operative system used in this work was 3.1.3.

We developed our game using event-driven programming and Objective-C as a programming language. To include AR capabilities, we used ARToolKitPlus 2.1.1. We used a game engine, SIO2 (1.4 version) (sio2interactive.com) to develop the game. SIO2 is written in C. It uses the OpenGL-ES 1.1 version and can import scenes created from Blender as well as other features. In our game, the 3D objects were modeled with Blender.

4. RESULTS

4.1 Study

Eighty-four children from 8 to 10 years old took part in the study (38 boys (45%), 46 girls (55%)). The children attended the Summer School of the UPV. The parents signed a consent form to allow their children to participate in this study. Questionnaires were used for the validation. Five questions were related to the participants' satisfaction with the game. Twelve questions focused on knowing the children's preferences and their opinions about AR. After playing the games, the children filled out the related questionnaires. The questionnaires were filled out in the same room where the activities took place. The children used each game for about 20-25 minutes. The children were counterbalanced and randomly assigned to one of two situations:

a) Children who played the AR iPhone game first and then the traditional game.

b) Children who played the traditional game first and then the AR iPhone game.

Percentages were analyzed from several questions. The question related to the ease of play was: 'Has it been easy to play with the AR device? (1: Not at all, 2: Slightly, 3: Moderately, 4: Very, 5: Extremely). Figure 8 shows the results. As can be observed, 49% of the participants considered the AR device extremely easy to play, manipulate and interact with. Only 3% thought that it was not at all easy to play with. Figure 9 shows that the third grade's students considered extremely easy to manipulate (56%), meanwhile the majority of fourth grade's students considered very easy to play with (49%). Moreover, none of the two grades considered not at all easy to play with the AR device. These results are in line with previous results using PCs (e.g. Juan et al. [7]).

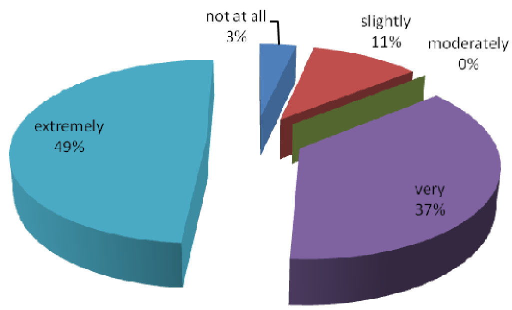

Figure 8. Ease of play with the AR device.

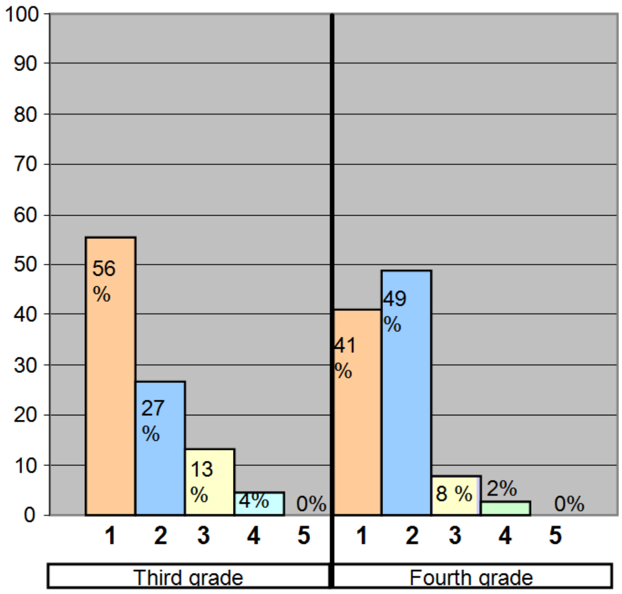

Figure 9. Ease of play with the AR device by grade. Where the numbers in abscissa correspond to: 1.-Extremely, 4.-Very, 3.-Moderately, 4.-Slightly, 5.-Not at all.

Related to the different types of interaction, the question was: While playing what type of interaction did you like the most? (1: The touch-screen (e.g. harvesting peanuts), 2: the accelerometer (e.g. the labyrinth), 3: AR (e.g. looking for animals), 4: Nothing, 5: I do not know. Figure 10 shows these results. The participants appreciated the most the use of the accelerometer (39%), followed by the use of AR (27%) and that the screen was tactile (27%). Figure 11 shows the preference about the interaction method by grade. As can be observed, the preferred interaction method was the accelerometer (36% in third grade and 41% in fourth grade), followed by AR in third grade and the touch-screen in fourth grade. However, these results should be corroborated in another study in which the different interaction methods were used for the same activities.

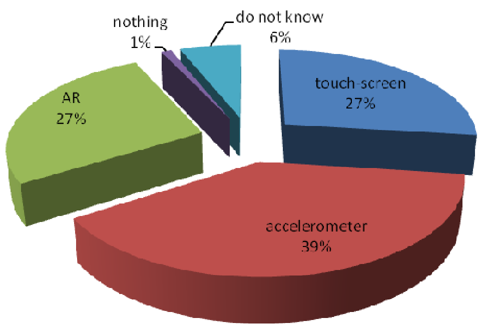

Figure 10. Preference about the interaction method.

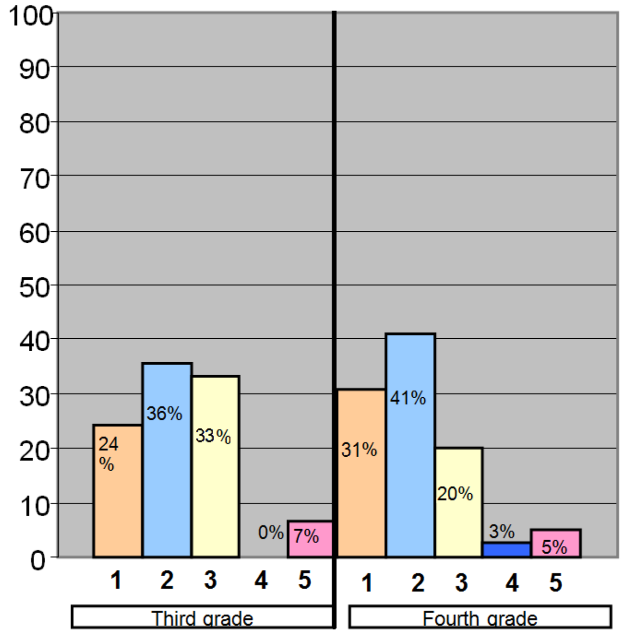

Figure 11. Preference about the interaction method by grade. Where the numbers in abscissa correspond to: 1.-Touch-screen, 2.-Accelerometer, 3.-AR, 4.-Nothing, 5.-Do not know.

Related to the predisposition to learn at school using AR, the question was: Do you like to learn new things at school using AR? (1: No, I am not interested, 2: I do not care, 3: Yes, I would love it). Figure 12 shows these results. The participants appreciated the most to incorporate AR in their learning activities at school (91%). Only 2% of the participants were not interested.

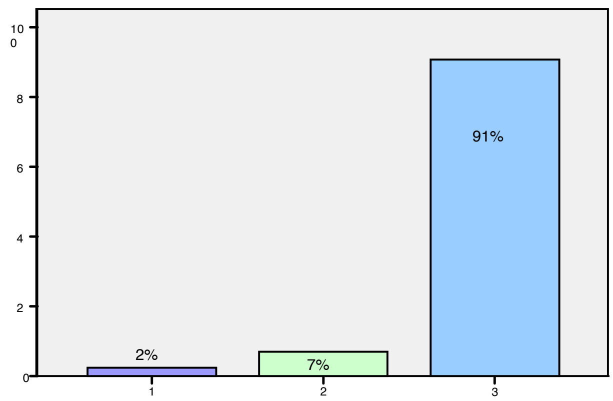

Figure 12. Predisposition to learn at school using AR. Where the numbers in abscissa correspond to: 1.-No, I am not interested, 2.-I do not care, 3.-Yes, I would love it.

Related to the preference about the game, the question was: Which game have you liked the most? (1: AR, 2: Traditional). The majority of the participants (81%) preferred the experience offered by the AR game over the traditional game. This result is in line with previous results using PCs (e.g. Juan et al. [7] [8]).

The number of children that preferred the AR version was higher when the traditional game was first played (90%). When the AR game was first played, this preference was 71%.

4.2 Design principles

As mentioned in the introduction section, Herrington et al. [2] presented design principles for mobile learning in higher education learning environments. Our context is not the same, because our game was used by children, neither the type of applications because we use AR. However, we took their principles as base for resuming our experience and we have adapted these design principles for mobile AR learning games for children:

1) Real world relevance: Use mobile AR learning games in real contexts. AR is used in the real world, this is the main advantage of using AR instead of Virtual Reality. However, it would be recommended to develop applications that exploit the benefits of AR. For example, in our case, it could be interesting to overlay information at a multicultural site (e.g. a field trip).
2) Mobile contexts: Use mobile AR learning games in contexts where learners are mobile. Sharples et al. [21] stated that mobile learning happens in contexts where the learner is mobile across topics, space and time. In our case, the game can be played in different spaces and time, and in a future with different topics.
3) Explore: Provide time for exploration of AR mobile technologies. Children can manipulate devices at early age. The new generations are 'digital natives'. They do not have the problems that their predecessors have. Nevertheless, every new device or game requires time for acquiring the basic knowledge. In the case of AR games for learning, we propose to include a short tutorial before start playing. In this tutorial, the different ways of interaction used in the game should be explained. We also propose to include a 'friendly pet' for this introduction and for guiding the children during their learning activity. In our case, with the help of this tutorial and the friendly pet, the children did not report problems with the game interaction. They also expressed their satisfaction with the tutorial and the guidance by the friendly pet.
4) AR, non-AR combination: Consider the combination of AR and non-AR. One possibility for this combination is shifting from an external perspective (AR) to an embedded agent (non-AR) allowing the player to become part of the game and this can create more engaging player's experiences [19]. In our case, the children reported that they have liked this combination.
5) Interaction combination: Combine different types of interactions. Mobile devices incorporate touch-screen interaction and accelerometer. Touch-screen interaction is one of the best ways of selecting elements on screen. The accelerometer is an interaction way that allows users to interact with the application only moving the device. When using AR and the selection of AR elements is required, one of the best interaction forms is touching the screen. The accelerometer also provides a very good interaction technique to be combined with AR. In any case, the application should be as intuitive as possible. The results of our study support the importance of the tactile screen and the accelerometer, and children's preference for the accelerometer.
6) Whenever: Use mobile AR learning games in any time. Mobile AR learning applications could include aspects that require that the children have to use the application at different times.
7) Wherever: Use mobile AR learning games in any space. Traditional learning occurs in formal settings (e.g. classrooms). Mobile AR learning is independent of location. It can occur in places such at home or in the park.
8) Whomsoever: Use mobile AR learning individually, collaboratively or competitively. Mobile learning can occur individually, collaboratively and competitively. It could be more adequate to use the individual, collaborative or competitive versions depend on the game. From our previous experiences, children prefer competitive, individual and collaborative, in this order of preference [22].
9) Affordances: Exploit the affordances of mobile AR technologies. Choose the technology that best fits your game. For example, although the camera that could be used in a PC has higher resolution that the camera in a mobile device, with the mobile device, the player gains in portability and its camera resolution could be enough for the requirements of the game. Another example could be the selection between mobile devices with different capabilities, for example choosing between a Samsung Galaxi Tab or an iPad 2. Their sizes, operative systems, weights or camera resolutions are different. The selection should depend on the best suitability for the application. Another suggestion is to focus the selection on the user, not in the technology, that is, do not force the use of new devices because we want to use them. For example, we can consider the use of the device screen or the inclusion of an eyewear such as Vuzix for visualization. The selection has to depend on the specific game. But, if the inclusion of additional elements to the mobile device is not extremely justified it would be better do not do it and exploit the affordances included in the available mobile devices.
10) Personalize: Use the students' devices. Using students' own mobile devices ensure that many of the features of the devices are well known and practiced [23]. If another device is used, players require time to familiarize with the new device. It is well-known that not all handheld devices have the same performance qualities, but as far as possible the applications should run in as many as different handheld devices as possible.

5. CONCLUSION

We have developed an AR iPhone game for learning multiculturalism and solidarity following different design principles. A study for AR subject preferences was carried out to choose the subject of the game. The data of this study are very valuable, and they could be considered for future edutainment developments, not only by ours, but also for any group. A study with 84 children comparing the AR game with traditional games was carried out. Four of the aspects included in this study have been presented in this paper. For interaction, the children preferred the use of the accelerometer (39%), followed by the use of AR (27%) and the tactile screen (27%). This result highlights the importance of this new type of interaction and encourages its use in different type of applications. For easiness, 49% of the participants considered that the AR device was extremely easy to play with. For the predisposition to use AR at school for learning, 91% of the participants appreciated this possibility. For the preference about the game, 81% of the participants preferred the AR experience. Based on the design of the game, its evaluation, our previous experiences with other learning games, and previous works of other researchers, we have adapted several design principles for mobile AR learning games for children. However, these design principles require more tests in order to proof their validity.

With regard to future work, a complete analysis of the results is in progress, specially the related with the learning outcomes of both games (AR and traditional). With the appearance of new handheld devices, a device with a larger screen could be used for comparison. Finally, although mobile devices do not have the capabilities of PCs, with the increased capacity of today's mobile phones and the technological advancements being made, there are increased opportunities to develop new and more powerful applications that were not possible five years ago. We believe that in the near future the technology of mobile devices will reach the capabilities of actual PCs and will go even further. Examples of this increasing power are, for example, the iPad 2, or the nintendo 3DS with an autostereoscopic 3D display and a 3D camera. With these new devices and with the devices that will appear in a near future, more engaging applications that exploit their affordances could be developed.

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7. REFERENCES

[1] Koh, R.K.C., Duh, H.B.L., Gu, J. 2010. An integrated design flow in user interface and interaction for enhancing mobile AR gaming experiences. In *Proceedings of the IEEE International Symposium On Mixed and Augmented Reality (ISMAR'10)*, 47 - 52.

[2] Herrington, A., Herrington, J., and Mantei, J. 2009. Design principles for mobile learning, http://ro.uow.edu.au/edupapers/88

[3] Kaufmann, H. 2004. Geometry Education with Augmented Reality, PhD Dissertation thesis, Vienna University of Technology.

[4] Larsen, L.B. Jensen, R.B., Jensen, K.L., Larsen, S. 2005. Development of an automatic pool trainer. In *Proceedings of the Conference on Advances in Computer Entertainment Technology (ACE'05)*, 83-87.

[5] Fjeld, M., Fredriksson, J., Ejdestig, M., Duca, F., Bötschi, K., Voegtli, B.M., Juchli, P. 2007. Tangible User Interface for Chemistry Education: Comparative Evaluation and Re-Design, In *Proceedings of the International Conference on Human Factors in Computing Systems (CHI'07)*, 805-808.

[6] Juan. M.C., Beatrice, F., Cano, J. 2008. Augmented Reality for learning the interior of the Human Body, In *Proceedings of the IEEE International Conference on Advanced Learning Technologies Learning technologies in the Information society (ICALT'08)*, 186-188.

[7] Juan, M. C., Carrizo, M., Giménez, M., Abad, F. 2011. Using an augmented reality game to find matching pairs, In *Proceedings of the 19th International Conference on Computer Graphics, Visualization and Computer Vision*, 59-66, http://wscg.zcu.cz/WSCG2011/!_2011_WSCG-Short_Papers.pdf

[8] Juan. M. C., Toffetti, G., Abad, F., Cano, J. 2010. Tangible cubes used as the user interface in an augmented reality game for edutainment, In *Proceedings of the IEEE International Conference on Advanced Learning Technologies Learning technologies in the Information society (ICALT'10)*, 599-603.

[9] Liu, T., Tan, T., C, Y. 2007. 2D barcode and Augmented Reality supported English learning system. In *Proceedings of the Computer and Information Science (ICIS'07)*, 5-10.

[10] Wang, K, Chen, L., Chu, P., Cheng, Y. 2009. A study on the design of Augmented Reality user interfaces for mobile learning systems in heritage temples. In *Proceedings of the Virtual and Mixed Reality*, LNCS, 5622: 282-290.

[11] O'Shea, P., Dede, C., Mitchell, R., Johnston, C. 2009. Lessons learned about designing augmented realities, *International Journal of Gaming and Computer-Mediated Simulations*. 1(1): 1-15.

[12] Juan, M.C., Furio, D., Alem, L., Ashworth, P., Cano, J. 2011. ARGreenet and BasicGreenet: Two mobile games for learning how to recycle. In *Proceedings of the 19th International Conference on Computer Graphics, Visualization and Computer Vision*, 25-32, http://wscg.zcu.cz/WSCG2011/!_2011_WSCG_Full_papers.pdf.

[13] Karpischek, S., Marforio, C., Godenzi, M., Heuel, S., Michahelles, F. 2009. Mobile augmented reality to identify mountains, In *Adjunct Proceedings of the 3rd European Conference on Ambient Intelligence (AmI-09)*, http://www.im.ethz.ch/people/karpischek/ami09_peaks_cr_20091024_sk.pdf.

[14] Sandor, C., Klinker, G. 2005. A rapid prototyping software infrastructure for user interfaces in ubiquitous augmented reality. *Personal Ubiquitous Comput*. 9(3): 169–185.

[15] Henrysson, A., Billinghurst, M. 2007. Using a mobile phone for 6 DOF mesh editing. In *Proceedings of the 7th ACM SIGCHI New Zealand Chapter's international Conference on Computer-Human interaction: Design Centered HCI* (CHINZ '07), 254: 9 – 16.

[16] Diverdi, S., Nurmi, D., Hollerer. T. 2003. A framework for generic interapplication interaction for 3D AR environments. In *Proceedings of the Augmented Reality Toolkit Workshop*, 86–93.

[17] Kato, H., Billinghurst, M., Poupyrev, I., Tetsutani, T., Tachibana, K. 2001. Tangible Augmented Reality for Human Computer Interaction. In *Proceedings of the 17th Nicograph (in japanese)*, 39-44.

[18] Zhou, F., Duh, H.B.L., Billinghurst, M. 2008. Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR. In *Proceedings of the 7th IEEE/ACM International Symposium on Mixed and Augmented Reality (ISMAR'08)*, 193-202.

[19] Dickey. M.D. 2005. Engaging By Design: How Engagement Strategies in Popular Computer and Video Games Can Inform Instructional Design. *Education Technology Research & Development*, 53(2): 67–83.

[20] Vitzthum. A. 2006. SSIML/AR: A Visual Language for the Abstract Specification of Augmented Reality User Interfaces, In *Proceedings of the IEEE Symposium on 3D User Interfaces*, 135- 142.

[21] Sharples, M., Taylor, J., & Vavoula, G. 2007. A theory of learning for the mobile age. In R. Andrews, and Haythornthwaite, C. (Ed.), The Sage Handbook of Elearning Research, 221-247. London: Sage.

[22] Alem, L., Furió, D., Juan, M.C., Ashworth, P., Recent trends of mobile collaborative augmented realty systems. Chapter: Evaluating children playing an augmented reality mobile game for learning about recycling, Ed. Springer, 2011

[23] Oliver, B., & Goerke, V. 2007. Australian undergraduates' use and ownership of emerging technologies: Implications and opportunities for creating engaging learning experiences for the Net Generation. *Australasian Journal of Educational Technology*, 23(2): 171-186.