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Supporting Learning with 3D Interactive Applications in Early Years

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Abstract. Early years education is an key element for the introduction of children in the education system. In order to improve this process, the aim of this study was to explore how guided interaction with 3D apps can fit into a preschool setting, how it can help children learn through playing and how it can improve their learning outcomes. A study was conducted with six classes of 87 students aged between 3 years to 6 years, over a 12-week period. Children used 10 inch Android tablets with a series of apps developed by our research team, about houses of the world, the skeleton & five senses and, animals. A quasi-experimental design based on a nonequivalent groups pretest and posttest design revealed that an active behavior and better learning outcomes are obtained by children participating in the experimental group.

Keywords: augmented reality, preschool, knowledge.

1 Introduction

Learning through playing and child-initiated activity is central to preschool education for children aged between 3 and 5. In this context, 3D interactive applications (apps) used on digital tablets can provide better support for mobility and collaborative use. They are easy to integrate into game activities and they also are funny. This range of technologies also increases pupils' confidence, supports learning in all the curricular areas, is more affordable for preschoolers and gives children the opportunity to work on competences and knowledge that they may develop in their life

3D apps as an educational tool can help the students to develop their own aptitude to learn by increasing self-esteem and confidence. They also have potential for promoting pleasure in learning by enhancing engagement, motivation and the desire to learn. Therefore, when students' activities are supported by guided interaction there is a potential to promote the three main areas of learning according to the Spanish legis-

lation: “Knowledge of self and personal autonomy”, “Social, physical and natural environments”, and “Languages”.

2 Related Work

Children’s learning with ICT goes beyond developing skills such as using a mouse or developing hand–eye coordination. When their encounters with ICT are supported by guided interaction there is a big potential to promote learning [1]. To maximize the learning benefits of ICT and 3D apps it is required a responsive, reflective and pedagogical response, encouraging pleasure and engagement as well as operational skills. Guided interaction as a mean to creating opportunities for supported learning with 3D interactive applications in early years is at the core of this research.

Progressive reduction in the cost of tablet devices is opening an opportunity to explore the introduction of more natural interfaces for the design of learning applications. Multitouch interaction has changed the way technology is adopted in classrooms for all ages [2]. Nowadays children are exposed to it on mobile phones and tablets at a very early age. Tablets portability is a great advantage to promote cooperation and collaboration though sharing activities that are very interesting from an educational point of view [3, 4, 5].

Couse and Chen [6] studied the use of tablet computers in early education by analyzing preschool children’s ease in adapting to tablet technology and its effectiveness in engaging them to draw. The study found significant differences in level of tablet use between sessions, and engagement increased with age. Participant teachers stated high child interest and children quickly developed ease with the stylus for drawing.

According to Kearney [7], educational apps should been designed to include aspects that are relevant to the child’s development: social experiences, expressive tools and control; so they can help children in their motor-skill and cognitive development.

Rankothge et al. [8] conducted a study on the introduction of a technology assisted tool for the learning skills development in early childhood. The final outcome was a Tablet PC based application to help the children in their learning experience at early ages. The developed tool improved the writing and speaking skills of the participant children in an entertainment based way.

Sandvik et al. [9] concluded that tablets devices were able to raise kindergarten children language and literacy skills through interaction with an image repository. It was tested that children developed the ability to pick up elements from the real-world contexts and connect them to technology.

Priyankara et al. [10] investigated how to support self-learning of preschoolers. They developed a tablet learning tool that facilitates self-learning of preschool kids. Their app allowed kids to develop cognitive and psychomotor skills such as drawing, writing, recognition of numbers, basic shapes and colors and logical thinking.

Other authors such as Zanchi et al. [11] have used tablet games to support preschool math learning, while Meyer [12] focused on the design of learning material for preschool teaching and learning through the example of a game-based platform for learning English.

3 Case Study

This paper shows the use of 3D interactive applications on tablets in an early years classroom as a tool to support the development of technological skills in a creative environment; environment which is rich in literacy and knowledge opportunities in the three main areas of learning: “Knowledge of self and personal autonomy”, “Social, physical and natural environments”, and “Languages”. The pilot project illustrates how a three-phase process can result in the development of: (1) emergent literacy, (2) digital access preschool learners and (3) basic knowledge concepts of three main areas of learning (Fig. 1).

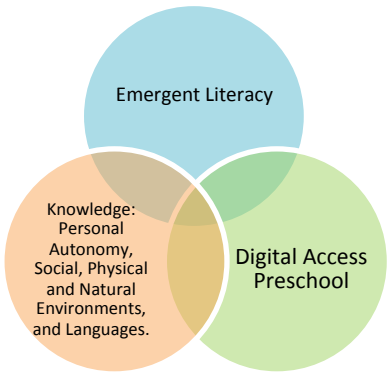

Fig. 1. The pilot project development context

The study was conducted on six groups of eighty seven preschoolers. All groups belonged to the second cycle of pre-primary education, according to the Spanish education system, but they were not the same age. The experiment was performed on a 12-week period. During this period, the students were introduced to the lessons of the skeleton & five senses, animals and houses of the world by using 3D apps on tablets.

Students were expected to acquire both general information about the studied topics and the three main areas of learning: “Knowledge of self and personal autonomy”, “Social, physical and natural environments”, and “Languages”.

This experience has been developed using 10 inch low cost Android tablets as the hardware platform. The 3D interactive applications provide two kinds of activities, “Lesson” and “Exercises”. In “Lesson” mode the contents allows the user to observe the scene; there is no more interaction than exploring 3D models from different points of view while listening to the corresponding audio. In “Exercises” mode two games are proposed: “Association”, where the user has to associate concepts, and “Composition”, where students are asked to compose an object using different elements.

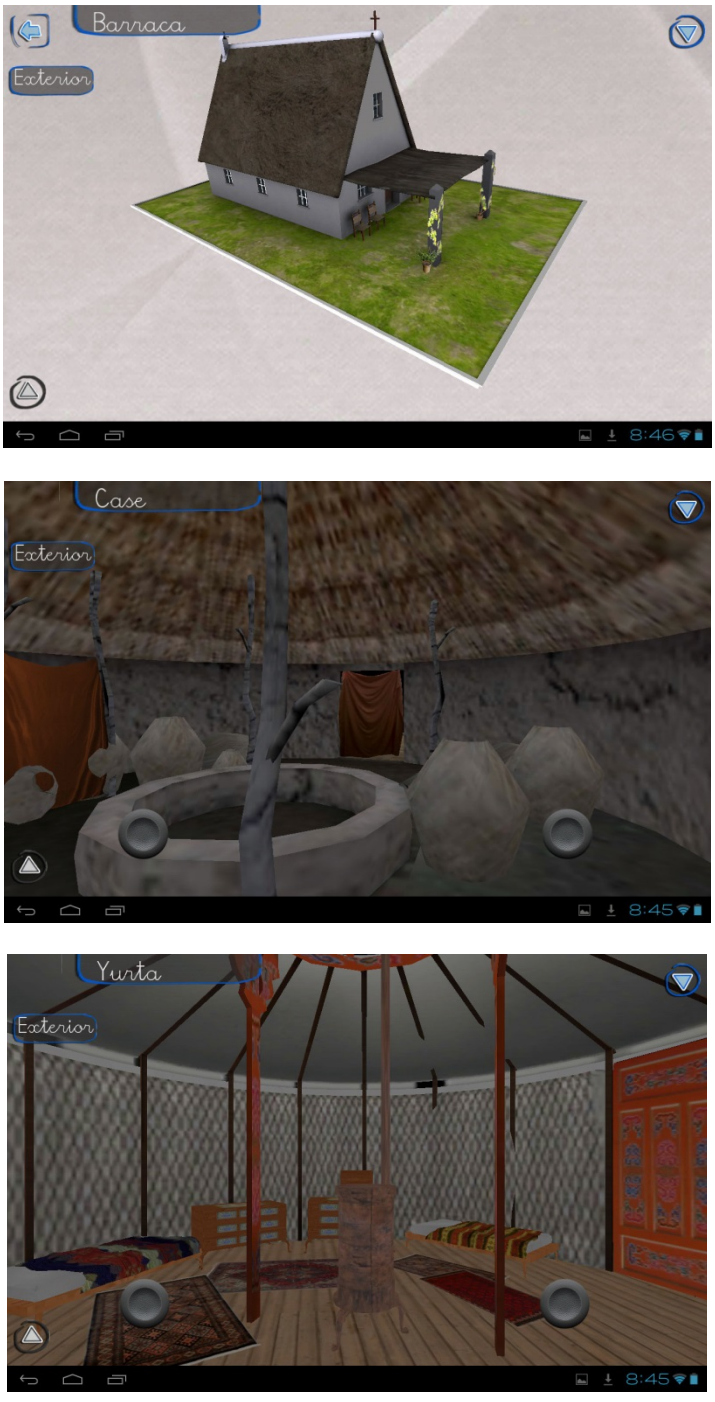

Fig. 2. Different screenshots of the “houses of world” 3D interactive app

Finally, in this research two versions of the didactic units were created, the difference between them was that the "experimental unit" provided the 3D interactive applications described above while de "control unit" provided traditional contents. In this way, both groups have the same educational curriculum content. Therefore, the independent variable of this research was the presence of 3D apps on tablets as a didactic tool. During the pilot study, teachers developed ways of actively guiding and extending children's learning through questioning, modeling, praising and acting as a supportive presence.

3.1 Research questions

The aim of this study were to explore how guided interaction of 3D Interactive Applications can fit into a preschool culture of child, how it can help them to learn through playing and how it can improve their learning outcomes, without losing sight of children's' many other responsibilities in the classroom. The research questions were:

1. Is there any difference in the students' learning results depending on which of the two proposed teaching scenarios they used?
2. Are there any differences among the three main curricular areas depending on which of the two proposed teaching scenarios are used?
3. Are there any difficulties or barriers that compromise the acceptability of 3D interactive applications on tablets in learning environments depending on kind of worked topics?

3.2 Procedure

The experiment followed a quasi-experimental design based on a nonequivalent group pretest-posttest [14]. Under this schema, one group (the experimental group) received the intervention (3D interactive applications) while the other group (the control group) does not use 3D apps. Therefore, not all the students participated in both learning scenarios. However, that research takes into account the main principles of applied ethics: profit maximization, fairness, confidentiality, autonomy and non-maleficence [15] [16].

3.3 Participants

The pilot study was conducted with six classes of 87 students aged between 3 years to 6 years, over a 12-week period. The sample consisted of: two groups of three-years-old, with 24 students; two groups of four-years-old, with 30 students; and two groups of five-years-old, with 33 students (Table 1). Initial conditions for all groups were not similar: each group was composed by a different number of children. In addition, its relationship with the ICT was very different. None of the groups had studied the topics previously. A text document was provided to students and their parents outlining the purpose of the research and their right to withdraw at any moment. Informed consent was obtained for every participant.

Table 1. Demographic subject information grouped by age

	Control Group			Experimental Group		
		Gender			Gender	
Age Group	**N**	M	F	**N**	M	F
3 to 4 years old	**12**	7	5	**12**	6	6
4 to 5 years old	**15**	8	7	**15**	7	8
5 to 6 years old	**16**	11	5	**17**	10	7
Total	**43**	26	17	**44**	23	21

3.4 Instrument

The assessment of the didactic units for each of the groups was performed by the participant teachers that completed an evaluative categorical scale for each of the participating students. This scale consisted of different items corresponding to the specific learning outcomes conforming to each of the three main learning areas. Each item was checked according the next categories: A (Achieved), IP (In process) and NA (Not Achieved).

In each area different items were evaluated, all of them were adapted to the age of the students. In the first area, the items were related to their possibilities of action and identity. While in the area number three, the items are more related to the acquisition of reading and writing ability, language and the visual arts. Items valued in the area number two are specific to the studied topics.

3.5 Treatment plan and analysis of information

Once the information collection was done, we proceeded to its analysis using SPSS program (v. 19). The nature of the variables has led us to apply different statistical techniques to achieve the main research goals, that is: direct reading of each of the variables (calculating frequencies and percentages), grouping variables (contingency tables, calculating frequencies and percentages), and performing nonparametric tests comparing several independent samples (Mann-Whitney *U* test taking a critical level α=.05)

To measure the internal consistency of students' categorical estimation scale a Cronbach alpha coefficient was calculated, yielding a value of .976, indicating that the instrument has high internal consistency. To consider the internal reliability of statements concerning the same construct as satisfactory, Cronbach alpha should be greater than 0.7 [3]. Construct validity was obtained from a content validity.

4 Results

Following are the results for each of the specific raised issues.

4.1 Research question 1

Is there any difference in the students' learning results depending on which of the two proposed teaching scenarios they used?

Table 2. Three curricular areas descriptive statistics for both gorups.

	Control Group			Experimental Group		
Areas	N	M	SD	N	M	SD
Knowledge of self and personal autonomy	43	1.70	0.67	44	2.66	0.48
Social, physical and natural environments	43	1.88	0.70	44	2.77	0.42
Languages	43	1.93	0.70	44	2.82	0.39
Total		1.84	0.58		2.75	0.35

Table 2 shows total descriptive statistics used to describe learning results in two teaching scenarios, using tablets o not using tablets. For all curricular areas, the mean scores corresponding at using tablets (M =2.75, SD = 0.35) are higher than those of not using tablets (M = 1.84, SD = 0.58). Whereas all mean scores not using tablets are below 2, while all mean scores using tablets are above 2. The highest differences among mean scores were yielded by "Knowledge of self and personal autonomy" area (M_c = 1.70, M_e = 2.66, M_e-M_c = 0.96). The lowest difference was produced by the "Social, physical and natural environments area" (M_c =1.88, M_e = 2.77, M_e-M_c = 0.89), and "Languages" area (M_c = 1.93, M_e = 2.82, M_e-M_c = 0.89).

For each of the three areas a Mann-Whitney U test was conducted to evaluate the hypothesis that control group students would score lower than experimental group students on the three curricular areas. The results of all the tests were in the expected direction and significant U_{area1} = 297, p_{area1} < .001, r_{area1} = 0.63; U_{area2} = 326, p_{area2} < .001, r_{area2} = 0.62; U_{area3} = 322, p_{area3} < .001, r_{area3} = 0.63.

Table 3. Mann-Whitney U test.

	Area 1	Area 2	Area 3
U	297	326	322
p	<.001	<.001	<.001
r	0.63	0.62	0.63

4.2 Research question 2

Are there any differences among the three main curricular areas depending on which of the two proposed teaching scenarios are used?

Table 4. Curricular areas descriptive statistics for both groups and grouped by student age.

	Control Group			Experimental Group		
3 to 4 years old	N	M	SD	N	M	SD
Knowledge of self and personal autonomy	12	1.58	0.67	12	2.58	0.51
Social, physical and natural environments	12	1.75	0.62	12	2.67	0.49
Languages	12	1.92	0.79	12	2.75	0.45
	Control Group			Experimental Group		
4 to 5 years old	N	M	SD	N	M	SD
Knowledge of self and personal autonomy	15	1.53	0.52	15	2.67	0.49
Social, physical and natural environments	15	1.73	0.59	15	2.80	0.41
Languages	15	1.73	0.46	15	2.87	0.35
	Control Group			Experimental Group		
5 to 6 years old	N	M	SD	N	M	SD
Knowledge of self and personal autonomy	16	1.94	0.77	17	2.71	0.47
Social, physical and natural environments	16	2.13	0.80	17	2.82	0.39
Languages	16	2.13	0.81	17	2.82	0.39

Table 4 shows the mean scores and standard deviations for each of the areas that compose the curriculum for levels. The highest mean score corresponds in all cases to experimental groups which could mean that the 3D apps learning scenario is better than the other scenario. Mean scores and standard deviations for the different levels are aligned with the results obtained in our own previous studies about supporting learning with 3D interactive applications [17]. The mean scores were higher in all cases. Regarding curricular areas, the highest differences among mean scores were yielded by "Knowledge of self and personal autonomy" area, 3 to 4 years old (M_c = 1.58, M_e = 2.58, M_e-M_c = 1.00), 4 to 5 years old (M_c =1.53, M_e = 2.67, M_e-M_c = 1.14) and 5 to 6 years old (M_c =1.94, M_e = 2.71, M_e-M_c = 0.77). It is high at the level of 4 to 5 years old and 5 to 6 years old and it is identical in the areas "Social, physical and natural environments" and "Languages" for the control group.

None of scores in the experimental group showed a mean value lower than 2.58, thus, these students outperformed the result by the traditional way of teaching the course and they were slightly more motivated when 3D apps were used.

Once again, a Mann-Whitney *U* test was conducted to evaluate the hypothesis that control group students would score lower than experimental group students on the three curricular areas. The results of all the tests were in the expected direction and significant as can be seen in Table 5.

Table 5. Mann-Whitney *U* test.

	3 to 4 vears old			4 to 5 vears old			5 to 6 vears old		
	Area 1	**Area 2**	**Area 3**	**Area 1**	**Area 2**	**Area 3**	**Area 1**	**Area 2**	**Area 3**
U	21.0	22.0	30.0	20.0	22.5	11.0	61.5	69.0	69.0
p	.002	.002	.008	<.001	<.001	<.001	.003	.006	.006
r	0.91	0.90	0.77	1.06	1.04	1.19	0.73	0.69	0.69

4.3 Research question 3

Are there any difficulties or barriers that compromise the acceptability of 3D interactive applications on tablets in learning environments depending on kind of worked topics?

Experimental group seems to reflect a higher improvement regarding to control group. Table 6 shows the descriptive statistics of the scores obtained by all students in the three topics for the experimental and control groups. An improvement in the final score can be observed when this system is applied to support learning with 3D interactive applications.

Table 6. Learning outcomes in three studied topics (descriptive statistics)

	Control Group			Experimental Group		
Topics	N	M	SD	N	M	SD
Skeleton & five senses	43	1.84	0.58	44	2.75	0.35
Animals	43	1.92	0.56	44	2.68	0.34
Houses of the world	43	2.02	0.54	44	2.80	0.27
Total		1.92	0.54		2.74	0.29

For each of the three topics a Mann-Whitney *U* test was performed to evaluate the hypothesis that control group students would score lower than experimental group students on the three topics. The results of all the tests were in the expected direction and significant $U_{topic1} = 188$, $p_{topic1} < .001$, $r_{topic1} = 1.02$; $U_{topic2} = 250$, $p_{topic2} < .001$, $r_{topic2} = 0.92$; $U_{topic3} = 196.5$, $p_{topic3} < .001$, $r_{topic3} = 0.99$.

Table 7. Mann-Whitney *U* test.

	Skeleton & five senses	**Animals**	**Houses of the world**
U	188	250	196.5
p	<.001	<.001	<.001
r	1.02	0.92	0.99

Table 8. Descriptive statistics in each didactic unit for control and experimental groups, gruoped by student age

	Control Group			Experimental Group		
3 to 4 years old	N	M	SD	N	M	SD
Skeleton & five senses	12	1.75	0.62	12	2.67	0.38
Animals	12	1.86	0.64	12	2.58	0.38
Houses of the world	12	2.03	0.69	12	2.78	0.36
	Control Group			Experimental Group		
4 to 5 years old	N	M	SD	N	M	SD
Skeleton & five senses	15	1.67	0.43	15	2.78	0.35
Animals	15	1.80	0.39	15	2.73	0.29
Houses of the world	15	1.89	0.45	15	2.73	0.26
	Control Group			Experimental Group		
5 to 6 years old	N	M	SD	N	M	SD
Skeleton & five senses	16	2.06	0.62	17	2.78	0.35
Animals	16	2.08	0.63	17	2.71	0.35
Houses of the world	16	2.13	0.52	17	2.86	0.21

Table 8 shows the mean scores and standard deviations for each of the topics for control and experimental groups according students' age. It shows that students who used the 3D apps achieved significantly better academic outcomes than those who did not use it. Moreover, the results of this study indicate that the use of the 3D interactive applications on tablets has important effects on the students' academic outcome. The students who used this system obtained better final grades.

Once again, for each of the three topics and for each of the three age groups a Mann-Whitney *U* test was performed to evaluate the hypothesis that control group students would score lower than experimental group students on the three topics. The results of all the tests were in the expected direction and significant, as can be seen in Table 9.

Table 9. Mann-Whitney *U* test.

	3 to 4 years old			4 to 5 years old			5 to 6 years old		
	Topic1	Topic2	Topic3	Topic1	Topic2	Topic3	Topic1	Topic2	Topic3
U	12,5	24,5	23,5	6,00	6,00	12,0	46,5	54,0	29,0
p	<.001	.005	.003	<.001	<.001	<.001	.001	.002	<.001
r	1.03	0.81	0.85	1.18	1.16	1.10	0.85	0.76	1.00

5 Discussion and conclusions

After analyzing the results obtained in this study, we observed that several of the issues addressed in the theoretical framework of the research are confirmed by the results presented above.

Data analysis reveals that active behavior is promoted on the children by using 3D interactive applications, moreover, students learn more when they are using the 3D apps and they get learning goals quicker if they used these applications. 3D Interactive Applications also promotes communication skills, promoting all kinds of interactions in the classroom between teacher and students, students and students, students and families, families and families and teachers and teachers. Finally, all study participants considered that the use of 3D apps is a good tool in the teaching-learning process.

Finally, although these are encouraging results, it is advisable to deploy similar research studies in extended periods of time to diminish the novelty effect that can be acting as a disturbing factor. It could be also useful to determine those other types of learning activities where 3D interactive applications on tablets can provide greater benefits than traditional methods.

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