3D Interactive Applications on Tablets for Preschoolers: Exploring the Human Skeleton and the Senses

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Abstract. Early years education is an important aspect for the future success of children in the education system. From this perspective, this paper describes the results of a study with preschool children using an interactive learning application on tablets. The project is arranged according to a three-phase process to promote the development of: (1) emergent literacy, (2) digital access for early years learners and (3) basic concepts in knowledge of the environment. The study was conducted with six classes of 87 students aged between 3 years to 6 years, over a 6-week period. During this period, the students were introduced to and engaged in the knowledge of the human skeleton and five senses by using a 3D interactive application on tablets. The quasi-experimental design was based on a nonequivalent groups pretest and posttest design. The interactive learning application was designed around three distinct interaction modes: presentation, exploration, manipulation and evaluation. These phases provided scaffolding for the students to engage with the technology and for the class teacher to develop her own skills. The results on the normalization tests for both control/experimental groups before the experiment were similar. The results after the experiment indicate that students who worked with tablets showed a slight improvement in results of learning outcomes.

Keywords: interactive 3D application, tablets, preschool, teaching/learning process.

1 Introduction

Early educational intervention promotes child advance and school success. The OECD [1] reports that students that attended preschool for one year or more score significantly more in the PISA test than students who did not do. It is important to have good early learning experiences to prepare compulsory education and foundation for life-long learning. Young children who are involved in positive and stimulating experiences and relationships with other children and environment are well equipped to reach their potential in life. In this respect, according to [2], [3], and [4], interaction with technology makes students participate actively in the learning process, promotes better understanding of the instruction, and improves the learning outcomes.

In this context, this work tries to contribute to explore the educational benefits of interactive 3D graphical applications in tablets. This technology offers many potential benefits, especially to motivate young students that show a very positive attitude to this kind of device and give the opportunity to share learning among peers. In this sense, tablets seem a good learning support where students can be provided with interesting environments to learn [5] and encourage collaborative work in the classroom. With this background, this work tries to contribute to the improvement of early childhood education by means of the following objectives:

- Promote educational innovation by a gradual change in teaching methodology in order to utilize the advantages provided by natural interaction with 2D and 3D contents.
- Analyze the possibilities that tablet applications can have on early childhood education to improve interaction between peers.
- Restructure the classroom environment to incorporate tablets devices in daily activities with a constructivist approach to learning.
- Assess improvements that can promote the learning of the students.

Therefore, we have tried to answer the following questions:

- What happens in the teaching and learning process when 3D interactive applications on tablets are used in the classroom?
- How can tablet educational applications help us to achieve the educational objectives?
- What kinds of interactions are produced when this technology is implemented in the classroom?

In order to answer the previous questions we have developed some educational contents and implemented a teaching/learning strategy around them that has been tested on a real preschool scenario using tablet devices.

1.1 Tablets in Preschool and Kindergarten

In recent years, interest in a more natural approach to interact with computers has gained momentum. Thus, progressively the traditional WIMP paradigm is evolving to a more natural interface, such as multitouch interaction. Some of these interface innovations come from new devices such as tablets and tabletops systems.

Tablets are devices, which allow portability and promote cooperation and collaboration though sharing activities that are very interesting from an educational point of view [6, 7, 8].

According to Kearney [9], a technological application is not only for fun. Tablet educational applications 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. Nevertheless, it is important not to forget that entertainment and fun enhance children's interest and learning.

Couse and Chen [10] studied the viability 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. Rankothge et al. [11] 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. [12] 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.

A common trend in the previous works is tablets promote that students share and help one another, ask for and provide information and explanations, and collaborate to solve problems. However, we know relatively little about how the use of interactive 3D contents on tablets can enhance and promote peer learning for preschoolers and help to create a constructivist learning environment. We interpret learning in early years as Papert [13] emphasizing active construction of knowledge and understanding. In this context, learning is seen as an active process of knowledge construction. Constructivist learning theory focuses on learning process instead of the content. For that reason, it emphasizes active knowledge through meaningful activities, interaction and communication with peers. This pedagogical model gives a more active role for students in their own learning process. 3D interactive applications on tablets can provide learning environments that support meaningful learning activities and interaction between peers.

In the next sections, a detailed description of the didactic contents is provided. Then, the experimental design is presented, followed by the results, discussion and conclusions.

2 Materials and Methods

2.1 Didactic Materials

In this study 10 inches low cost Android tablets were selected as the hardware platform. Performance and cost were the main reasons to select this equipment. The didactic application consisted in a content launcher, and an installation tool. It was also provided an installation manual to promote its easy set up.

The installation tool consists of a conventional apk file, which can be downloaded from Android's Play Store. Nevertheless, the installation was expected to be set up by a teacher, who launched the selected content for his students.

The application structure consists of three different parts: a launcher menu, which is designed to manage a collection of 2D and 3D interactive contents. It also allows the user to launch a specific educational module by selecting a specific content and language through different menus. The launcher was originally designed to be used by any user; however, in this study only teachers managed it. In fact, it could be used directly by children, but this was considered irrelevant for the finality of this study and for this reason this functionality was limited.

Application's interface allows kindergarten children to navigate through different information. Users are allowed to freely select the information to show, and they are also enabled to return to previous information if they wanted. Besides, just by touching interface elements like buttons and scroll bars, the system enables to control an auditory narrative (play, pause and stop), provides a user help guide, and a context-sensitive help on the action that is being performed at the moment. Moreover, the interface allows the visualization of models and procures interaction with 2D and 3D models. Furthermore, GUI information can be hided or shown to improve 3D model explorations by dragging labels in opposite directions. Therefore, when every element of the interface is shown, left side buttons can give access to different activities, as presented below (Fig.1). In addition, in the lower side of the screen, there is a rectangle reserved to show detailed explanations in text format. Note that those explanations are also shown as an auditory narrative. Also, note that this text box incorporates an automatic scroll to support long texts.

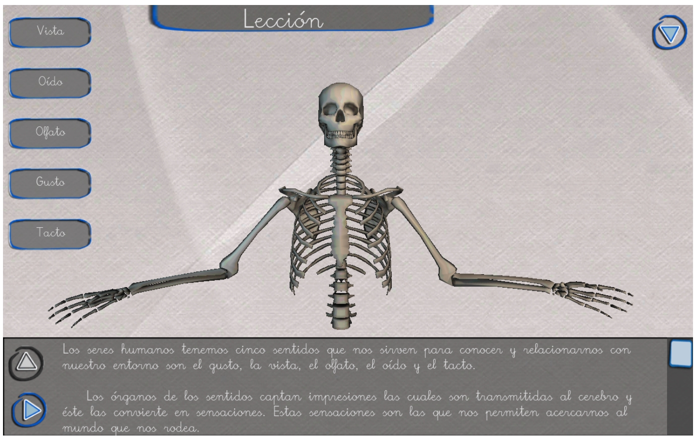

Fig. 1. 3D Interactive Application where some of its interface elements are shown deployed.

The last part is the main view. Main view occupies most of the screen and it shows 3D models, which can be interacted by users directly by touching the screen. 3D models can be dragged, rotated and escalated through natural gestures, enhancing user visualization of models.

The Skeleton Module provides two kinds of activities, "Lesson" and "Exercises". On the one hand, "Lesson" allows 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. This module is composed of five subactivities, which can be accessed by a set of buttons located at the left of the screen: “Bones system”, “Bone Joints”, “Skeleton” and “Types of Bones”. Each sub-activity presents the most relevant information related to its topic. In order to control the user interaction, user navigates through menus pressing buttons (Fig. 2).

If the user would want to return to previous information, he just had to press the escape button of tablet device. On the other hand, “Exercises” are a compilation of five games: “Joints classification”, where user has to classify the different bone joints between its kinds; “Touch the Joint”, in this game students are asked to touch a specific joint while a skeleton is moving; “Fix the skeleton”, in this puzzle-like game children must fix the skeleton dragging its parts to the proper place; “Bones types”, in this game it is shown different glowing bones and students must classify them; and “Touch the Bone”, where a complete skeleton is shown, and students are asked to touch the correct bone. In every game, it is also shown information about correct and wrong answers to boost children self-learning and autonomy.

Fig. 2. Skeleton Module. GUI elements deployed.

In a similar way than in the Skeleton Module, the Senses Module provides two kinds of activities, “Lesson” and “Exercises”. In this case, in Lesson mode the contents taught are the five senses: “sight” (Fig. 3), “taste”, “hearing”, “smell” and “touch”.

In “Exercises” mode are proposed two games: “Association”, where user has to associate different objects to the most relevant sense which allows its recognition; and “Composition”, where students are asked to match a sense with different parts of a skull. It is important to mention that the two applications resources were initially designed for primary school students, but after a preliminary evaluation with preschoolers, it was observed that they were able to access the basic functionality of the application without any problem.

Fig. 3. Interface characteristics. Senses Module.

2.2 Participants

The research involved six groups of eighty seven preschoolers, with ages between three and five years from the public school Virgen de los Desamparados in Orihuela (Spain) and their teachers. All groups belonged to the second cycle of pre-primary education, according to the Spanish education system, but they were from different level. The sample consisted of: two groups of three-year-olds, with 24 students; two groups of four-year-olds, with 30 students; and two groups of five-year-olds, with 33 students (Table 1). One group of each age was taken as the control group, while the other was taken as the experimental group. The participant teachers had received the same training.

Table 1. Demographic Information of Subjects by Age Group

	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

The school is located in a rural area. It is one of the seventeen pilot technological schools in the province of Alicante (Spain). The school is fully equipped with technology and count on a team of teachers experienced in ICT, which works hard to improve the use of ICT in school. Regarding the students participating in our research, they have been using ICT in school since they came to it; therefore, there are children who have been using ICT in class previously and others which are having their first experience with the ICT in this course. Students work every day with technology in their own classrooms, where they have several computers and an interactive whiteboard.

2.3 Experimental design and method

In this research, a nonequivalent group pretest and posttest [14] design has been chosen. Under this scheme, one group (the experimental group) received the intervention consisting in using the 3D interactive applications on tablets (students from the experimental group can be seen in Fig. 4), while the other group (the control group) does not use it. The intervention was done in a natural situation, without a random selection of groups [15]. Initial conditions for all groups weren´t 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 topic of the Human Skeleton and the Senses previously.

This experience has been developed using an active methodology, based on communication and research. This approach entails taking an area of interest –the Human Skeleton and the Senses– and using these topics as a basis for an in-depth enquiry or research. Areas of learning are not simply linked by a topic; they are integrated as a result of the investigative process. Knowledge and skills are not taught in isolation, but rather acquired and practiced within a meaningful context that makes sense to children. The methodology of work is representative of a pedagogy that stems from a positive image of the young child as a competent learner who is capable of taking an active role in their education. The provocation shows the inclusive potential and how they can enthuse children of all aptitudes and abilities, as well as motivate children to want to learn by building upon their interests.

On having used this methodology, the teachers were deeply implied providing feedback data about student experiences, bearing in mind the age and evolutionary characteristics of the pupils. The chosen didactic unit for all groups was “the Human Skeleton and the Senses”. Two versions of these didactic materials were created. The only difference between them was that the “experimental unit” provided the 3D interactive applications described in the previous section. In this way, both units have the same educational curriculum content. Therefore, the independent variable of this research was the presence of 3D interactive applications on tablets as a didactic tool, and the dependent variable was the ease of use.

On the other hand, all preschool students worked properly following the didactic guides developed by participant teachers. However it was the first time they used the tablets in the classroom. The experimental groups were divided into three groups and the participant teachers familiarized each group with the 3D interactive application on tablets. The participant teachers demonstrated how to use the application of sense (lesson and exercises) and each child spent a few minutes practicing with it on the tablet. The working sessions with tablets had a duration of three weeks and students worked in pairs and small groups (4 or 5 children).

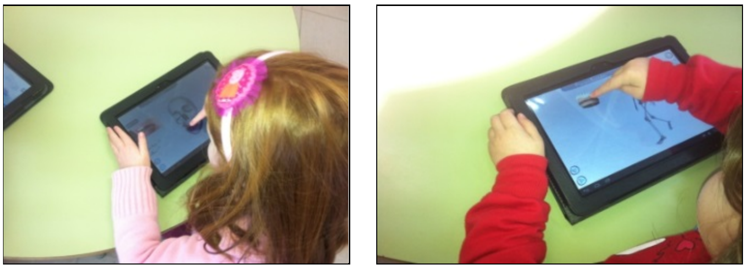

Fig.4. Children using 3D interactive applications on tablets.

The assessment of experimental and control groups was performed using an evaluative categorical scale completed by teachers (see Table 2). This scale consisted of 20 items, where each item was checked according to the following categories: A (Achieved), IP (In Progress) and NA (Not Achieved). This test was performed twice, before implementing the program (pretest) and after implementing the program (post-test).

Table 2. Students' categorical estimation scale

Pupil:	NA- Not Achieved IP- In progress A- Achieved		
Item		**Criteria**	
Skeleton part			
• Child recognizes backbone	NA	IP	A
• Child recognizes cranium	NA	IP	A
• Child recognizes mandible	NA	IP	A
• Child recognizes scapula	NA	IP	A
• Child recognizes clavicle	NA	IP	A
• Child recognizes ribs	NA	IP	A
• Child recognizes humerus	NA	IP	A
• Child recognizes radius	NA	IP	A
• Child recognizes ulna	NA	IP	A
• Child recognizes femur	NA	IP	A
• Child recognizes tibia	NA	IP	A
• Child recognizes fibula	NA	IP	A
Knowledge about joints:			
• Child recognizes wrist	NA	IP	A
• Child recognizes elbow	NA	IP	A
• Child recognizes fingers	NA	IP	A
• Child recognizes knee	NA	IP	A
• Child recognizes ankle	NA	IP	A
• Child recognizes heel	NA	IP	A
Knowledge about sight:			
• Child recognizes iris	NA	IP	A
• Child recognizes pupil	NA	IP	A
• Child recognizes retina	NA	IP	A
• Child recognizes optic nerve	NA	IP	A

Knowledge about hearing:			
• Child recognizes outer ear	NA	IP	A
• Child recognizes middle ear	NA	IP	A
• Child recognizes inner ear	NA	IP	A
• Child recognizes cochlea	NA	IP	A
Knowledge about taste:			
• Child recognizes salty	NA	IP	A
• Child recognizes sweet	NA	IP	A
• Child recognizes bitter	NA	IP	A
• Child recognizes sour	NA	IP	A
Knowledge about smell:			
• Child recognizes nasal cavity	NA	IP	A
• Child recognizes olfactory bulb	NA	IP	A
• Child recognizes cartilage	NA	IP	A
• Child recognizes nose	NA	IP	A
Knowledge about touch:			
• Child recognizes epidermis	NA	IP	A
• Child recognizes dermis	NA	IP	A
• Child recognizes sweat gland	NA	IP	A
• Child recognizes nerve	NA	IP	A

Besides, there was an assessment of levels of tablet use. It was also performed using an evaluative categorical scale and it was completed by teachers too. Levels of tablet use were coded according to Table 3.

Table 3. Definitions levels of Tablet Use

	Definition
Level 1: Explore/Experiment	Child tries to figure out what the tablet can do, clicking on different options to see what will happen if….
Level 2: Investigate	Child tries to figure out how to use the tablet to obtain information (e.g., How can I know the names of the bones?)
Level 3: Apply the knowledge	The child puts in function the knowledge acquired to realize the tasks.

Finally, there was an interview with participant teachers about how 3D interactive applications helped to create constructivist learning environments. In this interview, some questions were related to interaction capabilities of the developed 3D applications and others related to the student learning process.

3 Results

Total scores for pretest and posttest in both experimental and control group are presented in Table 4.

Table 4. Total scores for pretest and posttest (absolute frequencies)

	Control Group			Experimental Group		
3 to 4 years old	A	IP	NA	A	IP	NA
TOTAL Pretest	2	26	56	2	27	55
TOTAL Postest	17	32	35	31	41	12
	Control Group			Experimental Group		
4 to 5 years old	A	IP	NA	A	IP	NA
TOTAL Pretest	9	19	72	10	17	73
TOTAL Postest	24	34	42	38	48	14
	Control Group			Experimental Group		
5 to 6 years old	A	IP	NA	A	IP	NA
TOTAL Pretest	14	20	78	14	22	76
TOTAL Postest	27	42	43	49	45	18

Table 5 summarizes the results obtained from applying the categorical estimation scale about levels of tablet use of in the experimental groups as defined in Table 3.

Table 5. Levels of use Tablet in unit "Skeleton and the Senses" (absolute frequencies)

	Experimental Group		
	1	2	3
3 to 4 years old	4	4	4
4 to 5 years old	4	5	6
5 to 6 years old	4	6	7
Total	12	15	17

Table 6 presents the detailed posttest results obtained from applying the categorical estimation scale presented in Table 2. Experimental group reflects a slight improvement with respect to control group although there is no statistical significant difference.

With respect to opinions expressed by participant teachers, it is important to note teachers provided evidences of children's interest and the feasibility of 3D applications on tablets for preschooler to create constructivist learning environments. All teachers perceived more interest in children and an improved interaction between peers and small groups. In general, all they agreed that tablets promotes dialogue and communication in learning situations, and students required less attention from teacher, as they worked in a more autonomous way. Regarding to the learning process, participating teachers in this study observed that 3D interactive apps helped to build a more meaningfully learning, where pupils learn by doing and discovering by themselves. Students were engaged in the construction of their own learning, and therefore the preschoolers developed a range of skills that will serve for future daily life. Other comments from participant teachers noted the excitement of children when they knew that they were going to use the 3D apps with the tablets and their curiosity to learn exploring these 3D environments.

Table 6. Learning outcomes in didactic unit "Skeleton and the Senses" (absolute frequencies)

	Control Group			Experimental Group		
3 to 4 years old	A	IP	NA	A	IP	NA
Skeleton part	2	5	5	4	7	1
Joints	2	4	6	5	5	2
Sight	3	5	4	5	6	1
Hearing	3	5	4	4	6	2
Taste	2	5	5	4	5	3
Smell	2	4	6	4	6	2
Touch	3	4	5	5	6	1
	Control Group			Experimental Group		
4 to 5 years old	A	IP	NA	A	IP	NA
Skeleton part	3	6	6	5	8	2
Joints	3	5	7	6	6	3
Sight	4	6	5	6	7	2
Hearing	4	6	5	5	7	3
Taste	3	6	6	5	6	4
Smell	3	5	7	5	7	3
Touch	4	5	6	6	7	2
	Control Group			Experimental Group		
5 to 6 years old	A	IP	NA	A	IP	NA
Skeleton part	4	6	6	7	8	2
Joints	3	6	7	8	6	3
Sight	4	6	6	6	9	2
Hearing	5	6	5	7	7	3
Taste	3	7	6	6	9	3
Smell	4	5	7	7	7	3
Touch	4	6	6	8	7	2

4 Discussion and Conclusions

Young children of 3 to 4 year old were able to quickly learn to use the 3D interactive applications on tablets as a medium for representing their ideas and to improve their learning. The children in this study were able to become comfortable using the 3D applications when adults had given them some instructions and when they worked collaboratively with their peers. As the children gained familiarity with the tablet, they became more independent, asking for less instruction and assistance from adults. This was to be expected, as independence leads to a deeper exploration and a fuller utilization of the technology to represent ideas in a more productive way. As a result, it has been made easier to encounter more situations that are new. Finally, the use of ICT did not influence the ease with which children became acclimated to this new technology.

The slight improvement in results of learning outcomes in didactic unit "Skeleton and the Senses" must be put in context. 3D interactive applications on tablets were one of the components of the didactic activities designed to support this learning unit. The learning process was organized around team work, and the 3D interactive applications were used by the preschoolers at their own pace and depending on their evolutionary characteristics. Contents in tablets served as a catalyst providing a real motivation and stimulus for the children, and teachers observed a very positive impact on students.

Participant teachers had no previous exposure to this technology, but it was easily integrated in the class dynamics. The perception of participant teachers was that 3D interactive applications on tablets improved considerably learning activities and supported students' constructive learning approach. Teachers considered the 3D applications a resource tailored to the characteristics of their students and thus it was useful for learning. When teachers provided social facilitation for children using the tablets in the form of scaffolding and scripting the environment, positive peer interaction significantly increased. The children reflected upon the interactive content before sharing and discuss about it with each other.

All study participants considered that the use of 3D interactive applications on tablets is a good tool in the teaching-learning process. The conclusions we reached in our experience of inclusion of tablets as a part of the teaching-learning process are the following:

- The use of tablets promotes opportunities to investigate different interests of students and for developing skills in applying knowledge to informal reasoning. The work of teaching improves with the use of these devices. Daily work is more playful and fun for both students and teachers.
- In spite of the age of the students, the preschool children learn more when they are using the 3D interactive applications on tablets and they also achieve more learning goals than if they are not using.
- 3D interactive applications on tablets promote communication skills. In this sense, all kind of interactions in the classroom are promoted: between teacher and students; students and students; students and families; families and families; and teachers and teachers.

The experience with the use of tablets has been very constructive for teachers and students. After this experience, participant teachers will encourage their colleagues to use it in their classrooms. With regard to the pupils, the engagement with technology does not appear to be a simple function of age, but rather a more complex relationship between technology characteristics and the use done of it.

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