Evaluating an Educational System Based on Projective Augmented Reality

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Abstract. *Augmented Reality has the potential to play an important role in education since it can help to motivate the students and foster the interaction between the content and the learners. In this work, we explore the potential of the ARBlocks, a dynamic blocks platform for educational activities using projective augmented reality and tangible user interfaces. A semi-experiment was carried out with two first grade groups in order to attest if the tool could help the development of their literacy skills. Three different metrics were used to evaluate it, being two quantitative and one qualitative. The evaluation indicated that the tool contributed to the student's educational development and fostered their literacy progress. In addition, the teacher was very enthusiastic of its use.*

1. Introduction

Technology is widely spread in different areas, such as entertainment, education and many others. Most of the students are already familiar with it. [Kenski 2007] explains that its arrival in schools implies a range of challenges to teachers, students and the pedagogical team since the technology brings a double challenge: to adapt schools to its advances and to guide the people involved to master critically this new media.

One piece of technology that has a huge potential to be a valuable educational tool is augmented reality [Consortium 2011]. Also known as AR, it consists in adding virtual elements to a real scene [Azuma et al. 2001]. AR applications combine virtual and real elements in a coherent way so users cannot differentiate them from the real scene.

Many researchers have identified AR's potential to the educational environment. [Silva et al. 2012] listed some educational applications that used it. [Radu 2012] analyzed 32 works that compare AR tools with non-AR systems. He describes some positive and negative aspects regarding the use of AR technology in educational applications.

Since there are many technologies being developed using AR, the impact of them in the educational setting is of utmost importance. Hence, it is important to evaluate these tools in order to know their real utility in the learning environment.

Considering the relevance of this topic, we conducted an evaluation of an AR system using different metrics and methods combined to measure its impact in the learning process. That being said, the contributions of this paper are: (1) a more complete methodology to evaluate the learning impact of an educational augmented reality system. It combines the use of different metrics as a way of compensating the weakness of each method, resulting in a more consistent result; (2) provide means to integrate a

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new technology with teachers' lesson plan; (3) share and discuss the experiences and challenges on evaluating the use of an AR educational tool.

This work is organized as follows: Section 2 shows related works regarding the use and evaluation of AR in education. In Section 3, the AR tool evaluated in this work is described. Section 4 presents the methodology used to conduct the evaluation. In Section 5, the evaluation results are presented and discussed. Finally, Section 6 draws some conclusions and suggests future directions for the research.

2. Related Works

There is a vast body of literature involving AR and education. There are applications from preschool [Radu and MacIntyre 2009] to high school [Almgren et al. 2005] and college [Blum et al. 2012]. This technology is also embedded in mobile phones [MIT 2012]. An example that has become widely known in this area is the Augmented Book [HITLabNZ 2011]. These books appear to be ordinary ones but when pointed to a camera, users can see their content in 3D.

The educational scenario is a very complex one. Therefore, it is very important to develop ways to evaluate technology devices introduced in the learning environment. Although AR is considered a new technology, there are many evaluations regarding this technology use for education purposes. In [Billinghurst and Dunser 2012], children's abilities to recall stories and comprehend written text through the use of an augmented book were evaluated. Other types of applications were also evaluated and all of them presented good results concerning the student's motivation and educational impact [Shelton and Hedley 2002].

The evaluation of AR systems is not restricted to applications for young students. In [Macedo et al. 2012], a learning object was created to support the teaching of a rotating magnetic field of a motor engine. It was tested with four groups of students. Three of them used the tool and one of them did not. The evaluation revealed that the experiment groups improved their understanding of the content more than the control group.

One important aspect that has been shown in different works is that AR helps to engage and motivate students to learn. According to [Juan et al. 2010], sometimes the benefit of AR is linked only to promote motivation and engagement among students.

Some works use different metrics systems, both qualitative and quantitative [Karoulis et al. 2006]. This way, the authors try to ensure the validity of their work and reinforce their conclusions. In [Sumadio and Rambli 2010], the authors used two different metrics to evaluate people's opinion about a portable AR science laboratory. Most of the participants involved did not know AR but after some explanation about it they seemed to understand what it is about and were enthusiastic of its use.

Something that is important to mention is that the majority of the works that evaluate AR does not completely involve the teachers in the preparation of the activities to be worked in class. This is an important step to foster the integration between the new technology devices and the teachers' lesson plan, which is very important for successful learning. This aspect was evidenced when some schools in Liverpool, NY, dropped their laptops after seeing no progress in the students learning [Hu 2007]. This fact highlighted that technology by itself cannot improve learning.

Hence, our work intends to conduct a semi-experiment to evaluate an augmented reality platform, the ARBlocks, with both teachers and students in class. The impact of the tool in student's literacy development was measured both quantitatively and qualitatively. Due to the tool's flexibility, the teacher was able to create the activities to be used in class.

3. ARBlocks

Teachers commonly use educational activities based on blocks as a concrete instrument to teach abstract concepts. Therefore, it is a useful tool for learning, especially when dealing with young kids [Zuckerman et al. 2005]. Depending on the class subject, the teacher may use a set of blocks with numbers or letters. However, the traditional blocks have the information printed on their faces requiring one set of blocks for every activity. Moreover, this tool does not provide any feedback for the students.

Based on this scenario, the authors decided to evaluate the educational use of ARBlocks, a system that can solve those limitations and still having the benefits of the traditional blocks [Roberto et al. 2011]. The system is aimed to teachers and provides the infrastructure so they can create educational activities using dynamic blocks, in which any information, such as letters, numbers, geometric forms, pictures and several other contents, can be displayed on their faces, as can be seen in Figure 1 (c). The ARBlocks can also provide visual and sonorous feedback for the students.

Figure 1. ARBlocks setup is shown on the left (a). The blocks, on the top right (b), were designed especially for children and have an empty area in the middle where the virtual content will be displayed, as seen in the bottom right (c). It is also possible to use the table as a projection and interaction area.

Thereby, the ARBlocks can enhance the teacher's possibilities for creating educational activities. They can use their imagination to create games and exercises that explore the tool's features for virtually any content. It has a tangible interface so it can hold all the educational benefits of this type of tools. Thus, the blocks used were conceived specifically for children. Design techniques were applied to determine the best shape, material and typography for them [Roberto et al. 2011], as shown in Figure 1 (b).

The dynamic information is placed on the blocks' face using projective AR [Bimber et al. 2005]. To achieve a correct projection restricted to the inner area of the blocks, the camera-projector system is automatically aligned, so the teacher does not have to worry about a complex setup to use the system.

Since the blocks are the projection surface, they cannot be texturized and must have a plain and white face to ensure the projection color quality. In order to track blocks with those characteristics, a frame marker was used [Roberto et al. 2013]. These kind of markers have a code on their border and an empty region inside where any information can be placed.

4. Evaluation

The evaluation of the ARBlocks was performed through an experiment in a public elementary school located at Recife, Pernambuco in 2012.

4.1. Experiment design

[Easterbrook et al. 2008] point out the usefulness of mixed methods in the research design. They highlight the importance of employing data collection and analysis techniques associated with both quantitative and qualitative data as a way of compensating the weakness of each method. Therefore, in our work, we followed a mixed method approach aiming more reliable results.

Our goal was to evaluate the impact of the ARBlocks in the literacy progress of year one students. In order to achieve this, a semi-experiment was conducted. Two quantitative metrics were used. The first one is a test to verify student's abilities to recall the content studied with the tool. Although most of the studies use only this type of test due to time constraints, it is widely known the difficulties to measure accurately the learning process through a single assessment. Some researchers point out the importance of a formative assessment in which the students are evaluated continuously during the learning process [Zabala and da F. Rosa 2007]. In order to compliment our metric, we also used the teacher's own formative evaluation as our second quantitative measure. This way we could have a better overview of student's progress throughout the year. Her evaluation assesses student's literacy skills. The teacher classifies them according to the psychogenesis of written language theory developed by Emilia Ferreiro [Ferreiro 1985]. The stages of written development proposed by the author are the following:

a) Pre-syllabic 1: they do not understand the relationship between oral and written language. They can write using drawings, scribbles or wavy lines;
b) Pre-syllabic 2: they can trace letters although they do not find any correspondence between written and oral language;
c) Syllabic (quantitative): they write one letter per syllable;
d) Syllabic (qualitative): they use one letter per syllable; however, they try to use letters that are related to what they hear;
e) Syllabic - alphabetic: they are able to establish a relationship between graphemes and phonemes in most words although they still write units smaller than a syllable;
f) Alphabetic: in which children can establish the relationship between letters, words and syllables.

As part of our qualitative metric, it was conducted a semi-structured interview with the teacher in order to see her perception of the children development.

[Fitzpatrick 2004] stress the need to involve teachers in the process of adopting new technology so the activities are integrated to their lesson plan and meaningful to the students. To involve teachers in the adoption of technology, we used the flexibility of the ARBlocks to support different applications and encouraged them to create the applications desired. Since the system does not have an authorship tool, the teacher needed to describe the activities so a programmer could develop the activities required.

4.2. Participants

The teacher involved in our research is graduated in pedagogy and is very interested in learning and using new technology in her class. She teaches two first grade classes, one in the morning shift and the other one in the afternoon. Each class has approximately 20 students. Her students were chosen for the experiment because the ARBlocks is a tool aimed for children from four to eight years old.

In the beginning of the year, she applied a test with all her students in which they had to write some object's names. She reapplies the same test approximately every two months in order to monitor student's development. Based on her test results, we decided, along with the teacher, to apply the tool in the morning shift group, which presented the lowest scores. The afternoon shift was our control group. The tool was applied in the morning shift group twice a week for four weeks.

4.3. Environment and System Setup

The experiments were conducted in the school's library since it provides a good space for the system setup and the students. In this experiment, the ARBlocks run in an ordinary laptop having an Intel Core 2 Duo with 2Ghz, 4 GB of RAM, an integrated graphics card, a built-in speaker for the sonorous feedback and Windows 7. The computer was connected to an Epson projector EB-X10, similar to those found in several schools nowadays. It was used a Microsoft webcam LifeCam Cinema, that is also a standard model.

The projector was attached to the Artograph Digital Art Projector Tripod and pointed down to one of the library's table. The webcam was taped on the top of the projector in order to see the entire projection area. Figure 1 (a) shows the environment and the system setup used in the experiments.

4.4. Activities

The activities proposed by the teacher involved mostly reading skills and phonemic awareness since this is one of the first steps to reach reading competence [Adams and Foorman 2005]. The teacher was working with rhymes so she requested for an activity in which students would match a block containing a picture, such as a "rat", with a region on the table that had another image to which their names rhyme, eg. a "cat". By doing the correct matching the students listened to the rhyme. Another activity replaced the image in the blocks by the pictures of the students and they had to match them with their own drawings with situations that rhymed with their names, such as "is using his computer" for the name Peter (see Figure 2 (a)).

Another activity requested involved nursery rhymes, in which students should complete a nursery rhyme they had been rehearsing in class. To do that, the nursery rhyme appeared on the table with some words missing that were in the blocks, and the students should place the correct word on its spot in the right order, as shown in Figure 2 (b). As they completed it, they listened to their own voices singing the nursery rhyme.

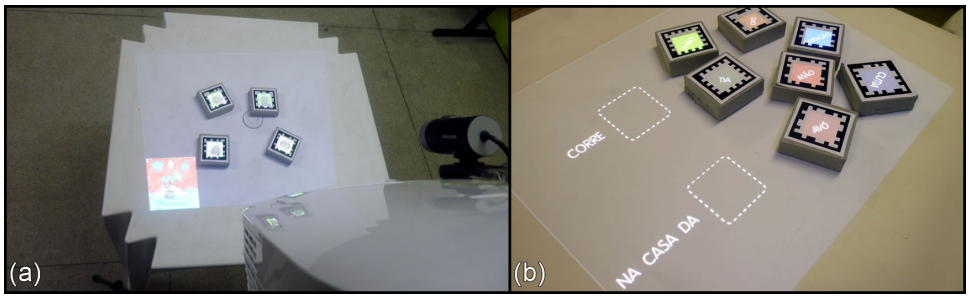

Figure 2. On (a) a drawing is shown on the table and the students had to match the pictures with the names that rhyme with them. On (b) the nursery rhyme activity requires children to complete the verses with the words in the blocks.

The sections were organized so that each child could interact with the blocks every visit. The class was divided in three groups of six to seven participants each, depending on the number of students attending the class. While one group was using the system, the others were engaged in other educational activities related to the same topic. Each section lasted about 30 to 45 minutes depending on the activity.

4.5. Evaluation

After the period using the ARBlocks, a test was applied with the morning shift that used the tool and the afternoon that did not use it, which was the control group. The test aimed to verify the content retention. It was elaborated by the teacher so students were familiar with it. The test consisted of four questions[1], three involving the content studied with the ARBlocks and one involving contents that were not practiced using the tool.

As mentioned above, for the purpose of our evaluation, we considered the assessment the teacher does periodically with the students. Her evaluation consists of presenting some pictures to the students and asking them to write its names the way they believe they are written[2]. After that, they read what they wrote to her so she can classify them according to Ferreiro's stages of written development. It is the same test she applied in the begining of the year.

As a qualitative evaluation, we conducted a semi-structured interview to ask her the positive and negative aspects regarding the tool and its use. It was also asked if she perceived any contribution of the tool to her students' development and if she would plan her lessons taking the tool into consideration in case it were available with an authorship program. The conversation was audio recorded and lasted approximately 20 minutes.

5. Results

According to the evaluation methodology applied in this work, the presentation of the results obtained will be divided in three parts: results of the test after the use of the tool

[1]See the *retention_test.pdf* at `http://db.tt/owNu1D86`
[2]See the *periodical_test.pdf* at `http://db.tt/ZXvTw4sh`

period, results of the teacher assessment and, results of the interview conducted with the teacher. Finally, a subsection discusses in detail the results.

The test applied after the period using the tool to both groups showed that the morning group had an equivalent score compared to the afternoon one regarding the questions about the topics worked with the ARBlocks. The chart seen in Figure 3 shows the average score for both groups divided by questions using grades from 0 to 10. The morning group, which showed a slower development before starting the evaluation in comparison to the afternoon group, achieved the same grade for the first question and a slight beneath score for the second one (7.88% lower). Both were addressed to rhyming. In the third question, about the nursery rhymes, the morning group achieved a slightly higher grade than the afternoon shift group (5.67% higher). In the last question, related to filling in the missing letter in the words, a subject that was not worked using the ARBlocks in both groups, the difference on the score was more evident (23.69% lower).

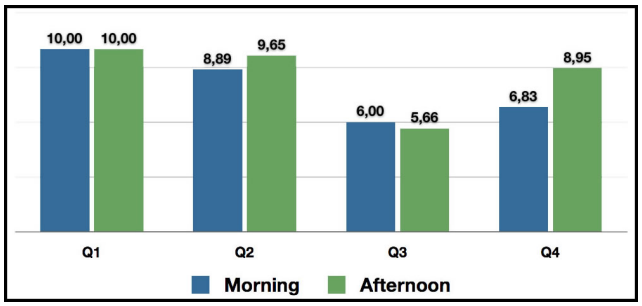

Figure 3. Average score of the morning and the afternoon shift groups separated by questions. Questions 1 to 3 were about topics worked with the ARBlocks and the question 4 was taught without the help of the tool.

The second quantitative metric was the formative assessment the teacher regularly applies with the students. The chart in Figure 4 reveals that in February most of the morning students were in the pre-syllabic 2 stage. In April we were able to find students in both syllabic stages. Between April and June, none of the students could be found in a more advanced writing stage, but they were all established in three stages (pre-syllabic 2 and syllabic quantitative and qualitative). Between June and September students were migrating through these three stages. The ARBlocks was used with the morning group during four weeks between August and September. The chart shows that after this period most of the students were in the syllabic stages and only four progressed to more advanced levels. Nevertheless, the teacher made this evaluation two weeks earlier in comparison to the two previous assessments. In December, the majority of the class was in the syllabic-alphabetic stage. The rest of the class was spread between the syllabic stages.

In Figure 4 we present the results of the teacher's assessment with the afternoon group. In the first assessment (February) we can see that most of the students were in the pre-syllabic 2 stage. However, we can see that there were students in all the stages of the development. In April, students started migrating from the pre-syllabic stages to the qualitative stages, although the majority of the class was in the pre-syllabic 2 stage. The syllabic-alphabetic and alphabetic stages did not change. In June, we can see that more students reached the syllabic-alphabetic and alphabetic stages. In September, the majority of the class was in the syllabic qualitative stage. By the end of the year, most of the

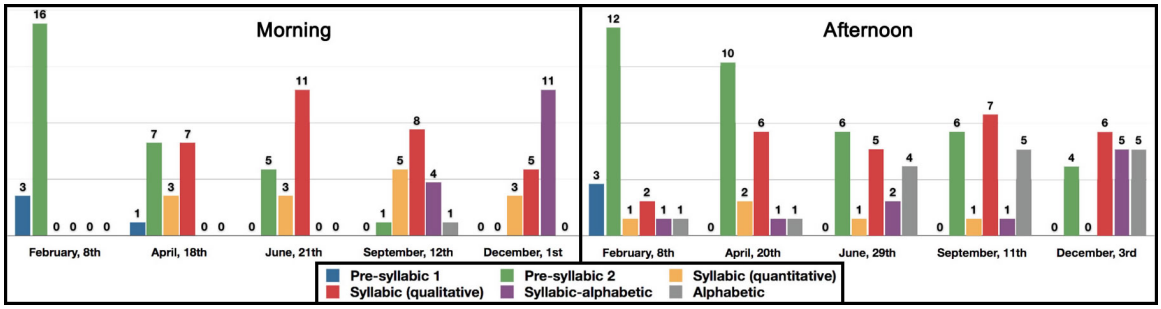

Figure 4. Number of students from the morning and afternoon shifts according to their writing development in the teacher's evaluations through the year.

students were spread over the three final stages, syllabic qualitative, syllabic-alphabetic and alphabetic. Four students remained in the pre-syllabic 2 stage.

Finally, in the semi-structured interview, the teacher was questioned about the use of the ARBlocks. According to her, the main advantage of the ARBlocks is that it provides different and enjoyable playful activities that can be related with the content worked in the classroom. She mentioned that the school has several educational software, but when the students go to the informatics laboratory they often use applications that are not linked with the classroom content.

5.1. Discussion

The results of the test applied after the use of the tool showed that, although the morning group started the year in a lower level of development, they reached similar levels to the afternoon group. In the last question of the test that was worked in the traditional way in both groups, we can see that the difference of their scores was higher. This indicates that augmented reality seems to have helped them to better grasp the content.

The students seemed to be very motivated by the tool and its use. They appeared to get attached to the tool and named it "the robot". The sonorous feedback was perceived as the ability of the robot to speak. They seemed to be excited in engaging in an activity different from their routine. This observations led the authors to discuss about how to design educational AR applications [Roberto et al. 2013]. During the interview, she mentioned that the children enjoyed using the ARBlocks and this extra motivation made them more focused to read. She said that the morning shift group did not seem to be willing to read and a few days after starting using the tool they became more interested in doing the activity.

Regarding the students' educational evolution, she claimed that the ARBlocks played an important role for children's educational evolution. According to her, it was not expected that any of the morning students would be in the alphabetic stage by September, and still there was one pupil in this stage and two more almost there, as seen in Figure 4. She mentioned that the evolution was faster than expected. She also mentioned one student that started to read during the ARBlocks' use. The teacher believes that this happened because this child became very motivated after using the tool.

It is important to mention that the student who reached the alphabetic stage during the use of the tool finished the year in the syllabic-alphabetic stage. This is normal since

the written development is not a linear process. Learners are always testing and retesting their hypothesis about the written language and, thus, consolidating their knowledge.

6. Conclusion

Although preliminary, the results supported our hypothesis that the ARBlocks can help to motivate students and foster the development of their literacy skills. The teacher provided a positive feedback regarding the tool and its use, highlighting its flexibility.

Regarding the teacher's regular evaluation, we believe that it is a good way to have an overview of student's development during the year. We could notice that in a smaller period of time, the children reached a good progress concerning their writing development. In the test applied after the ARBlocks use, we could see that in the questions that had been worked with the tool, students reached a satisfactory score.

Through the interview, the teacher seemed surprised to see one of her students in the alphabetic stage in September. We noticed that she was very enthusiastic with the use of the tool and she believed that the students were extremely engaged in the activities.

For further works, we believe that the system must be used for a longer period of time and with more groups of students. It is also important to test the tool with different teachers in order to discern and evaluate the impact of teacher's methodology in the use of the device. These approaches might help to hinder the confounding aspects that may affect the evaluation.

We believe that the use of different metrics should be encouraged in further studies since it facilitates to have a better overview of the impact of the tools.

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