An interactive application based on augmented reality and rules-based reasoning to support educational activities of high school students

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***Abstract*—According to the latest estimates of the United Nations Educational, Scientific and Cultural Organization (UNESCO), in 2017, more than 617 million children and adolescents were not achieving minimum proficiency levels regarding reading and mathematics. In this line, it is essential for children and youth developing mainstays for solving problems and adequately understanding the information around them. These mainstays are strongly related to logical and mathematical skills. Therefore, in this paper, we present an educational tool that uses augmented reality to provide interactive exercises for the following areas: functions, areas, volumes, angles, and the Pythagorean theorem. Similarly, our proposal incorporates a decision support system that suggests to a given student what activities and exercises must solve. The validation process of the tools was carried out with the support of 179 volunteers.**

***Index Terms*—Augmented reality; Mathematics; Support Decision System; Children and youth.**

I. Introduction

There's no doubt that among universal languages features mathematics, whether its conceived by man as an instrument of language for other sciences to understand the world or as a particular metacognitive process, we must be able to appreciate from nature in the form of numeric concepts [1].

Anyway it can be understood, in both ways it's appreciable that mathematics is an inexcusable competence for life, because it places us in reality and enhances the interrelation with the context, thus the OECD, within the framework of the PISA tests [2] characterizes it as:

> *the ability of a individual to formulate, employ and interpret mathematics in different contexts. Including mathematical reasoning and the use of mathematical concepts, procedures, data and mathematical tools to describe, explain and predict phenomena. It helps individuals to recognize the role that mathematics plays in the world and issue well-founded judgments and decisions that constructive, committed and thoughtful citizens need.*

Likewise, the problem that involves the process of teaching/learning mathematics is universal, on the one hand regarding the teaching staff count with a reduced number of experts for training or the existing ones are from the discipline without combining whats required from the didactic, on the other hand, educational action may be irrelevant when the content is decontextualized, unconnected with other disciplines [3].

If we add to the above, the tendency thatin Latin America math training curricula are weak and inadequate learning materials, we are far from being able to talk about development education in the framework of an interconnected world economy. Considering the didactic principle that knowledge is cumulative, we cannot expect good mathematics results for middle-level students, since in Ecuador and Peru and some Central America countries, in the application of regional tests promoted by the Latin American Laboratory for the Evaluation of the Quality of Education (LLECE) 50% of its students generally reach the lowest level of performance in the third grade and also keep weak results in mathematics in the sixth grade [4].

In Ecuador, although National Institute for Educational Evaluation (INEVAL), referring to results of participation in PISA-D claims that "Ecuador had the best performance in all evaluated subjects. When comparing the results of Ecuador

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with other countries in the region, the results are within the average", a more impartial reading would be that this average is below just over 100 points compared to countries such as Chile and Uruguay, which is confirmed when INEVAL itself recognizes that "The percentage of students who didn't reach the basic level of skills in Ecuador is higher in the mathematical domain: 70%", which means of every 100 teenagers aged 15 only 30 of them can perform routine procedures or mathematically represent a simple situation (for example, compare the total distance between two alternative routes or convert prices to another currency) [5].

There is no doubt that ICTs will modify education and along with it to society; it's ensured changing to a education that explores culture, works on projects and makes research and debate a regular process, it's not gonna happen for the simple fact of incorporating novel contents in disciplines including mathematics, or for introducing educational platforms; It will happen because ICTs and their interactive apps will allow students go from being apprentices to co-teachers who learn and promote learning in others, therefore the educational space is transferred from the classroom to society in general [6].

II. Related work

Teachers in charge of instructing students in different branches of learning are constantly searching for new tools and ways to reach their students, optimize class hours and enhance the results compared to those obtained following a traditional session. Such is the case of Cazar y Arroyo, who present an investigation to know how the augmented reality affects the teaching processes of the Biology subject to secondary school students. In their research are involved two classes. In the class "A" the subject is imparted applying augmented reality and the course "B" is imparted in a traditional method. Having as a result that when applying the augmented reality tool, it has a positive impact on the student's general learning in the subject compared to the class that followed the traditional method. In addition, a survey showed statistically that the tool is very well received by students and teachers [7].

In the same way, Gutirrez R. researchs on a didactic experience that university students who study to be teachers in Social Sciences have. The objective of the research was know the students' perception of augmented reality and its application in teaching/learning processes and their level of knowledge of the tool. The results of the research showed a positive acceptance by future teachers and their motivation to apply ICTs in educational training processes. They also recognize the didactic benefits of their use, which is the motivation and interactive learning [8].

Along the same line, the augmented reality app goes beyond teaching, such is the case of Lucero, M., & Luzdary, A. who propose a virtual didactic assistant with augmented reality, for children between 3 and 5 years old of a Children's Center, this assistant is based on combining elements of the real world with elements of a virtual environment. The objective is help the children of the center to develop their cognitive functions, since it's considered at that age the human brain develops 90%, and it's when the main neurological connections are created. The developed app allows to optimize the learning process of children through the activities and dynamics of the app, taking advantage of the hook and the attraction that children have towards it [9].

Augmented reality has been gaining strength in recent years and is used in several areas, as Medina-Carrión A., who develops an app as a complement for museum tours. This app is based on augmented reality to teach children the Cañari and Inca cultures in the Ecuadorian context and has an expert system based on rules for the recommendation of tours to museum exhibits. The app was validated by thirty children from three different schools, who showed a high level of interest in the app [10].

III. General system architecture

The general components of the proposed interactive app architecture can be seen in Figure 1. Counting with three layers:

A. User Interface Layer

The user interface layer is responsible for showing the user either teacher or student the content of the app, this layer is divided into the interface for mobile device and the pc interface.

On the pc interface, Figure 2. we found an evaluation on the mathematic knowledge of five subject-matters: Functions, Areas, Volumes, Angles and Pythagorean Theorem. Students must solve and enter the correct answer. The content of the evaluation has been developed by teachers who are experts in the area and it was applied to real students. Each evaluated area has six multiple-choice questions, the selected answers will be used for the recommendation of the areas that need reinforcements.

The interface shown by the mobile app covers the augmented reality content for math reinforcement. In this interface the student can select the area to reinforce and the specific subject-matter.

1) Augmented Reality Content: The proposed app has been developed in Unity which is an development engine for videogames and interactive apps. The engine facilitates integration of Vuforia technology, which is highly used for the augmented reality apps development. Vuforia allows you to create a "Target" database which are the images the device will recognize through the camera to display 3D content and integrate it into the Unity project.

To optimize student's learning in the mathematic areax, three modes were developed that together cover a robust teaching method of the subject, each mode makes use of specific targets and are delivered to the student by the teacher:

- Augmented reality Video: in this option the imdicidual uses his mobile device to point the target printed on a sheet as see a video that explains all the content of the subject-matter, the student can replay the times he thought is necessary, Figure 3.

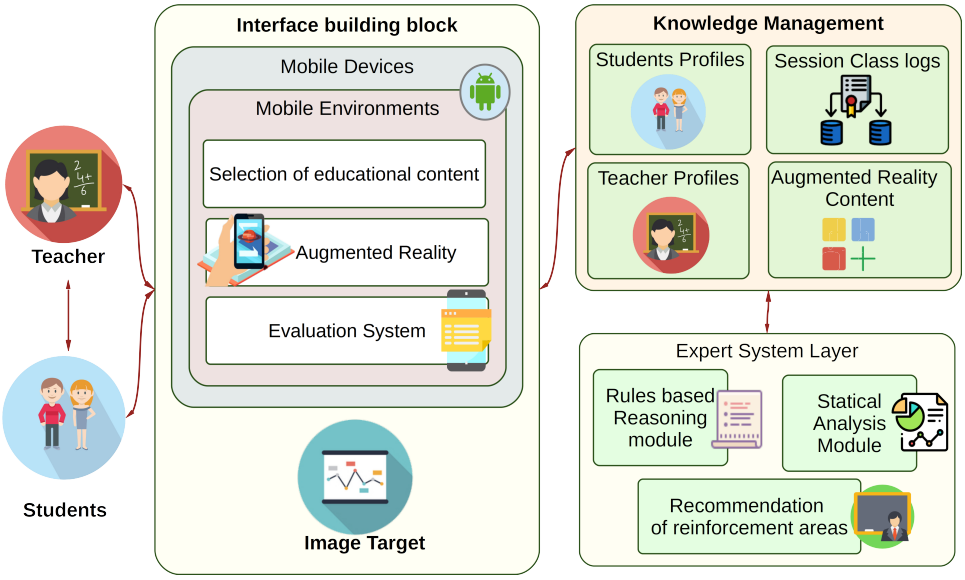

Fig. 1. The general ecosystem architecture and the main modules and layers that constitute it.

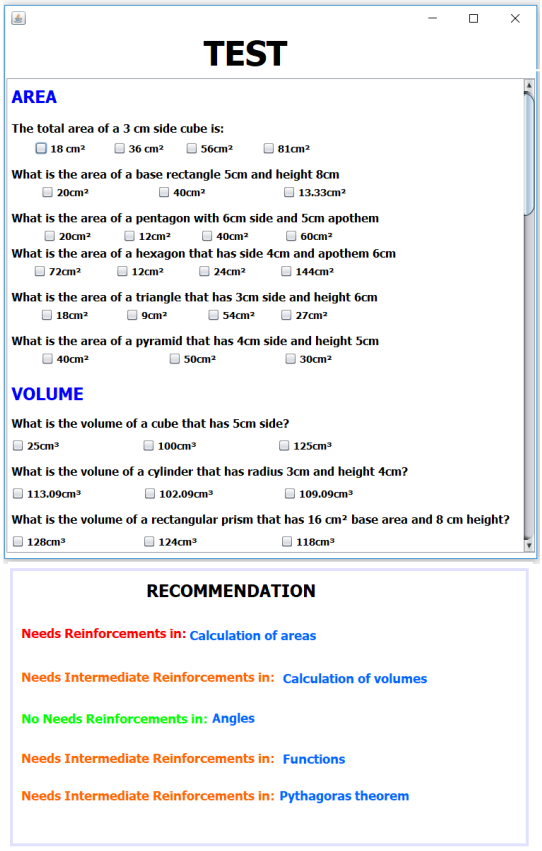

Fig. 2. Two screenshots of the PC application to provide suggestions of which contents must reinforced by the students. The top image presents the test that must filled by students, whereas the bottom image shows the suggestions.

- Augmented Reality Simulation: in this option when target is pointed, the augmented reality 3D content is shown, in this case there's a prism which the student can rotate and change their dissensions to later calculate its volume, it's shown in a menu in addition showing the formulas necessary for calculation, Figure 4.
- Augmented Reality Assessment: In this option the student validates their knowledge through an exercise that is projected pointing the mobile device to the target, Figure 5. The student will have two attempts to respond correctly, the answers obtained are stored for future analysis by the teacher.

Fig. 3. A screenshot of the augmented reality video that is displayed when the mobile app detects a "video-mark".

B. Expert System Layer

The app has an expert system based on rules for recommend areas to be reinforced by the student, it was developed in CLIPS, a tool for expert systems development which communicates to JAVA with app developed through CLIPSJNI library. The expert system receives as input the successes in the evaluation applied to the student, infers through the rules

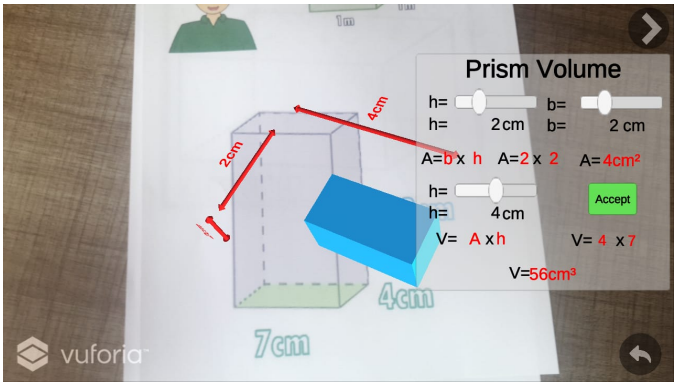

Fig. 4. A screenshot of the mobile application that shows 3D objects with which the students can interact.

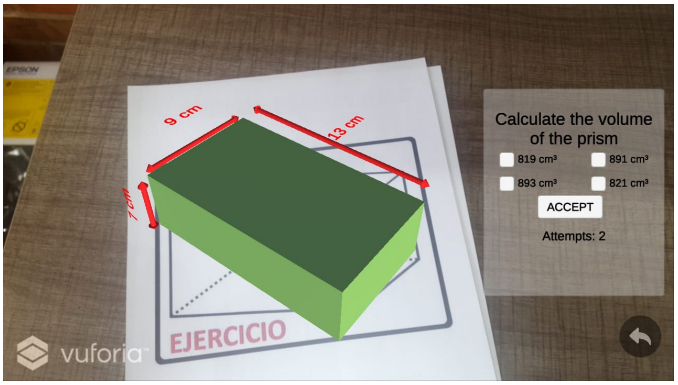

Fig. 5. A screenshot of the mobile application that shows an exercise that must accomplished by the students.

obtained by the expert teachers and returns the areas students need reinforcements.

C. Knowledge Management Layer

In this layer the information of both the student and the teacher is stored, storing their academic profile and personal data, as well as on the part of the student the results of the evaluation, the recommended areas to be reinforced and the responses obtained in the evaluation of the mobile app. This information can be visualized by the Teacher through the Logs of the class sessions that the app stores.

IV. Pilot Experiments and Preliminary Results

The results obtained are presented by means of a survey applied to 179 children of "Educational Unit United States of America" educational unit between 11 and 18 years. The survey was previously validated using the Cronbach's Alpha test [11], which was 0.86. Prior to the application of the survey, the questions that formed the theoretical construct were validated by experts in: area: systems engineering, psychology, medicine and anthropology.

The objective of the pilot experiment was to determine the students' perceptions regarding the following criteria:

- How did the students perceive educational software?
- Is the app useful to learn how to solve mathematical exercises?
- The students accept using the math APP as a support tool to work in the classroom?

Figure 6 shows that among the students interviewed, the positive perception of the ease of use of the math APP ("Totally easy", "Very easy", "Neither easy nor difficult") predominates using perception through of the Likert scale. Similarly, students would like to have the math APP as part of their classes. Well, they have a highly positive perception ("I would like very much", "I would like to" , "I don't care").

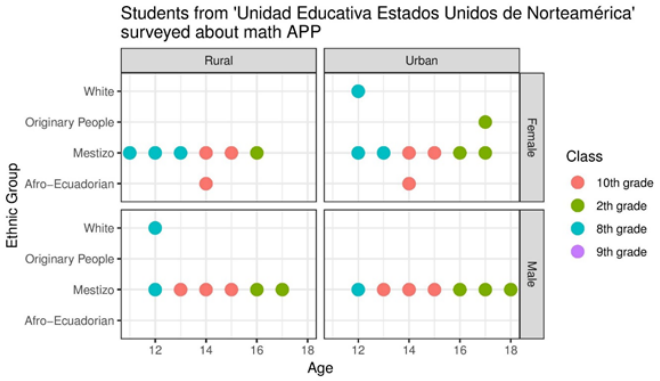

Fig. 6. Demographic characteristics of the students that participated as volunteers in the pilot experiment.

Through the survey you can see how the proposed math APP is able to facilitate the learning of math topics to students of the "United States Educational Unit" regardless of gender, and ethnicity (considering that the predominant in this unit is mestizo). On the other hand, there is evidence of positive acceptance by boys and girls between 11 and 18 years old of said educational unit, despite this, depending on the degree of difficulty, it can be said that children in the upper grades are able to perform more complex exercises easily, while those of lower years are able to easily solve less complex exercises. In other words, the APP facilitates solving exercises in relation to the traditional methods (Figure 7). Tools such as the proposal app are shown as fundamental for the learning of complex topics such as mathematics, because they allow students to improve their skills solving exercises and understanding abstract concepts.

V. Conclusion

According to the surveys applied to high school students, they agree the use of a mathematical application helps them to the challenges detected in the classroom, being a playful way to learn and becoming a positive tool that teachers can use in their classes. The survey also proofs high acceptance of students regarding the use of the appl and they expressed they wanted use it to learn mathematics in and out of classrooms.

Experts in education area have expressed their total pleasure towards the application and mention the importance of this kind of tools which they can support the teaching process of secondary school students in the different curriculum subjects.

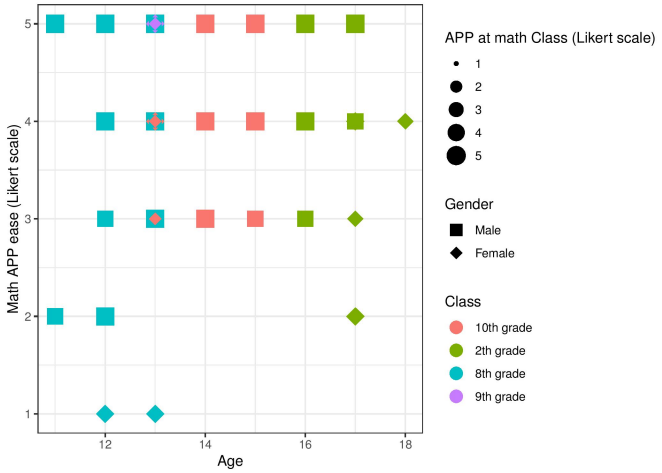

Fig. 7. Students' perceptions regarding the usability of the mobile application. The figure shows the perceptions organized according to the course, gender, and preference (size of the marks).

Nowadays, it is necessary to improve the learning process of assignments such as mathematics in institutions of middle education. In Latin America, the level of proficiency in mathematics and chemistry are very low in several countries. For these reasons, this kind of application is fundamental to motivate youth learning.

As lines of future work we propose the following:

- To develop a module to register the students' feedback regarding the reinforcement exercises and activities suggested by the expert system.
- To develop a module to generate collaborative exercises that must be solved in groups of students.

ACKNOWLEDGMENT

This work was funded by the Cátedra UNESCO Tecnologías de Apoyo para la Inclusión Educativa and the research project "Sistemas Inteligentes de Soporte a la Educación Especial (SINSAE v5)" of the Universidad Politécnica Salesiana.

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