Architecture Proposal under a Virtual Reality Ecosystem to Support the Teaching of Basic Mathematics in Elementary Education

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Abstract

One of the big problems facing Latin America in education is undoubtedly the educational backwardness that is present and worsens over time, México is no stranger to this problem, in recent years and especially in times of pandemic COVID-19 brought important educational challenges that aggravated the problems. To this is added the difficulty faced by students in learning mathematics, due to the teaching methods used that do not motivate or arouse the interest of students. The objective of this research is to design digital environments focused on virtual reality as a support in the learning of basic mathematics for elementary school students. It is proposed to build a software architecture based on an ecosystem for virtual reality applications, the proposed ecosystem is composed of providers and consumers of educational content (children), elementary school teachers who will generate and design basic mathematics activities and elementary school students will consume the applications through the activities within different virtual environments and with different interaction dynamics making use of virtual reality viewers. It is expected that the architecture can establish the basis for the design and production of Virtual Reality applications that allow the conformation of learning communities in mathematics through the virtual reality learning ecosystem.

Keywords

Virtual Reality, Elementary Education, Digital Ecosystem

1. Introduction

In Mexico, educational backwardness has always been a problem. Estimates by the Consejo Nacional de Evaluación de la Política de Desarrollo Social (CONEVAL) indicate that in 1990 educational backwardness was 14% in the population between 6 and 15 years of age, a decade later the percentage was reduced to 9.7% and in 2010 the percentage of educational backwardness was 5.9%. [1]. Nationally, between 2018 and 2020 educational backwardness increased by 0.3 percentage points from 19.0% to 19.2%, respectively. [2]. Competency-based education in Mexico was ambiguously mentioned in the educational plans of 1993, Luis Benavides at the head of the

CITIE 2022: International Congress of Trends in Educational Innovation, November 08–10, 2022, Arequipa, Peru
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National Technical Education Council and his team of collaborators proposed it as ”Performance Profiles” during the Salinas administration. In 2004, the national education system formally established competency-based education at the preschool level and five years later, in 2009, it was implemented at all other educational levels.[3]. In Mexico, the results obtained in the areas of reading, mathematics, and science are well below the OECD (Organization for Economic Cooperation and Development) average. [4]. In the area of mathematics, 56% of students are at the lowest proficiency levels, and only 0.5% reach high proficiency levels, in comparison with OECD, 24% have low performance and 11% achieve high performance in mathematics. [4]. The results of the PLANEA test (Plan Nacional para la Evaluación de los Aprendizajes) applied to students in sixth grade of primary school in 2018 reveal that 59% of students have an insufficient command in the area of mathematics while 15% have sufficient command and only 8% have an outstanding command. [5]. Virtual reality technologies help improve student motivation and learning experience[6].

The playful nature is important to create a competitive satisfaction in the individual, it provides optimal challenges to the users without being overwhelming obstacles. [7]. It is proposed to build a software architecture based on an ecosystem for virtual reality applications. The proposed ecosystem is composed of providers and consumers of educational content (children), elementary school teachers who will generate and design basic mathematics activities, and elementary school students who will consume the applications through the activities within different virtual environments and with different interaction dynamics using virtual reality viewers.

2. Background

2.1. Digital ecosystem

A digital ecosystem is a distributed, adaptive, open socio-technical system with properties of self-organization, scalability, and sustainability inspired by natural ecosystems. Digital ecosystem models are informed by knowledge of natural ecosystems, especially for aspects related to competition and collaboration among diverse entities [8].

The ecosystems can be structured under an architecture, offering services and resources from the software engineering perspective. For them, software development process models are required from the different communities of users to be served [9]

2.2. Virtual reality in education

Virtual reality in computing is defined as the natural form of interaction between a person and a computer by immersing the user in a virtual environment. The immersion sensation is achieved through the stimulation of senses such as: sight, hearing, touch, taste and smell [10]. Virtual reality as an educational tool is capable of assisting the educational model by providing improvements in the teaching and learning process, especially in the area of student and teacher motivation. Adding gamification, it can be considered as another alternative for the solution of specific educational demands. The use of virtual reality does not exclude more traditional methodologies, on the contrary, it is possible to adapt it to different teaching modalities and

methodologies [10].
potential, since it makes the interaction more intuitive, allowing students to use the teaching tools in a more natural way [11]. Virtual reality is an asynchronous tool, it does not require simultaneous conxetion of teachers and students, it allows students to have contact with the contents at a time and place according to their needs. It is also presented as an alternative for distance education [10]

3. Related works

[12] proposes a three-dimensional (3-D) virtual reality (VR) model called the Sun and Moon System. The goal of this study was to use 3-D VR technology to build and evaluate a model suitable for observing the movements of the sun, moon, and earth and appropriate for learning and teaching in elementary school. To evaluate the natural science learning outcomes of elementary school students who used the VR learning environment, a non-equivalent group quasi-experimental design was adopted.
The results indicate that the incorporation of VR models in science education positively influences the performance of elementary school students. However, this research focused on a desktop virtual reality system and not an immersive one. In addition, one of the tools used for outcome assessment was multiple-choice questionnaires. This tool is not always the best for the assessment of knowledge acquired through a virtual environment. It is desirable to implement follow-up evaluations to know and compare the knowledge retention of the groups.
[13] aimed to investigate how the spatial reasoning skills of elementary school students were affected by the consumption and production of extended virtual reality video content. Students were given a four-week intervention, the first two weeks to consume virtual reality videos, the third to create their own videos using 360-degree video cameras, and the final week they had the opportunity to view the videos they had created.
The students were administered a spatial reasoning pre and post-test to measure the change in spatial reasoning ability over the four weeks. The results indicated that the consumption and production of VR videos led to an improvement in the overall spatial reasoning ability of elementary school students learning science. used off-the-shelf applications, no VR application was developed.
Four limitations are noted:

- Having a small sample size affects the generalization of results and statistical analyses.
- The lack of a control group to compare the results obtained by the intervention group.
- Only one pre-test and one post-test were performed.
- The intervention duration was short.

[14] Examine the effects of augmented reality technology on stories in terms of narrative ability, story length, and creativity, and also examine the correlations between these variables. A posttest-only design with a non-equivalent group model was used. According to the results, the mean scores of all variables for the experimental group were higher than those of the control group. A limitation of the study was not using any pretest. The researchers used the

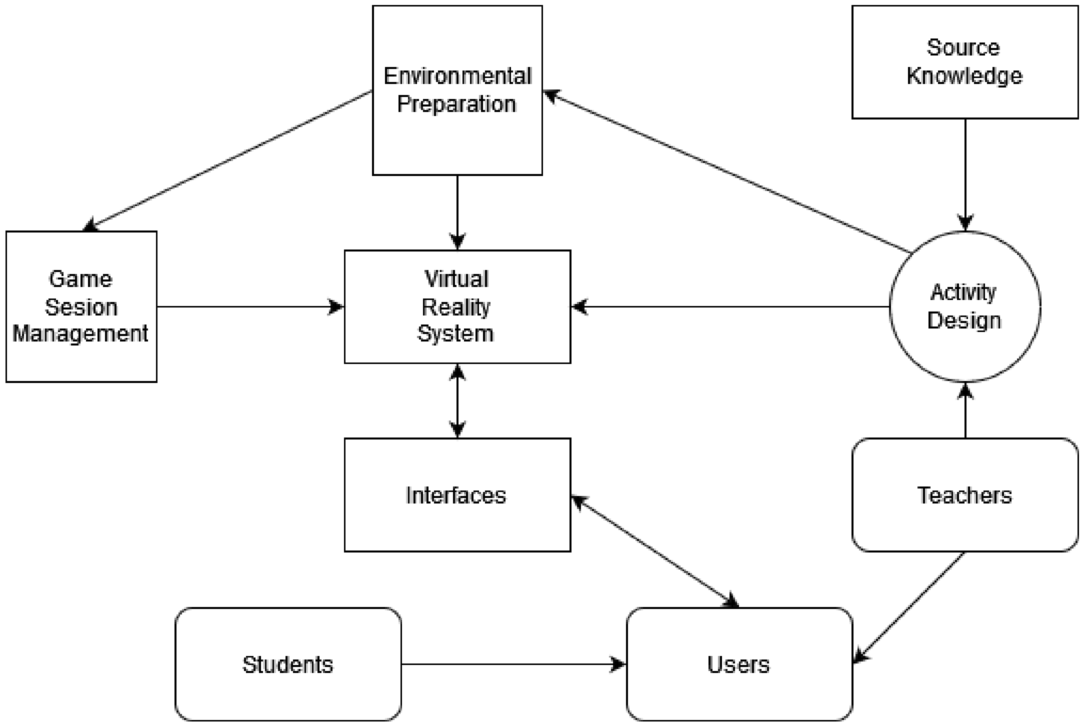

Figure 1: Model of virtual reality systems for education inspired by [15].

BuildAR program as a tool to generate marker-based AR scenarios.

4. Proposal

4.1. Source knowledge

It represents resources or tools available for the teaching of basic mathematics such as didactic materials, books, illustrations, educational software, etc. Teachers will determine the sources of knowledge to use to base the necessary activities so that students can achieve the defined competencies. The competencies to be achieved will define the mathematical concepts that need to be learned.

4.2. Activity Design

In the Activity Design module, the teacher will be in charge of collecting the necessary information to select the user profile, determine the math skills that the student should learn and the activities to achieve it.
The user profile consists of student information such as:

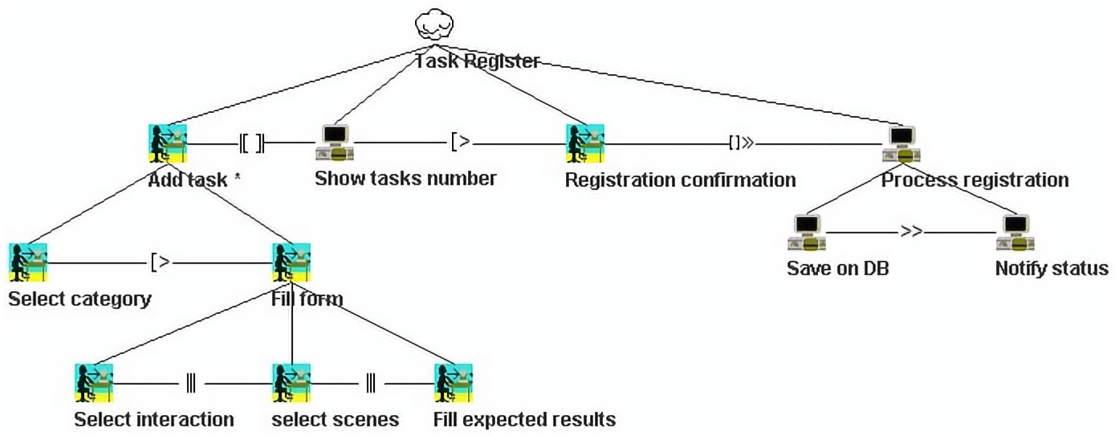

Figure 2: Process to register tasks.

- Competencies achieved in mathematics.
- Age.
- School grade.

The primary teachers must follow the process to register the tasks, the process consists of four main activities, starting with an interaction activity ”add task”, this is iterative so a primary teacher can register one or more tasks, the activity ”show task number” is the next in the process, it is an activity that the application must perform, it maintains a concurrent communication relationship, this means that while the primary teacher is adding new tasks the number of activities shown can be updated. The ”registration confirmation” activity is an interaction task, where the primary teacher must confirm the registration of the previously added tasks. The previous activities are invalidated once the process reaches this task. The last activity is defined as ”process registration” and is a task that the application must perform, it is only spoken when the information from the previous steps is available.

4.3. Virtual Reality System

The virtual reality system is software capable of generating an environment in which the user is an active participant and interacts with the virtual world using multisensory interfaces [15]. A virtual environment has features such as navigation, scale, point of view, interaction with the environment, etc.
These features can change at the user's convenience and simulate situations that would be difficult to replicate in the real world. Virtual environments will have the following characteristics:

- Interaction mode.
- Scenario.
- 3D models.

Each environment should have unique characteristics in order to expand the teaching resources.

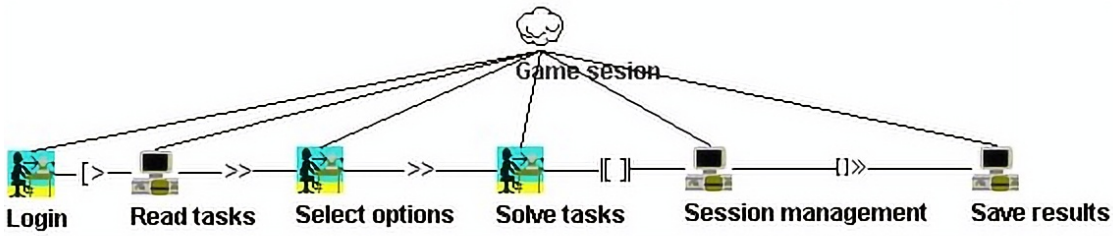

Figure 3: Process for game session.

4.4. Environmental Preparation

The virtual environments will be designed with the information from the activities. In this process, the 3D models, scenarios, and interaction modes will be defined.

4.5. Game Sesion Management

Manages the level of difficulty of the activities according to the results of the users. There will be three levels: initial, basic and intermediate. The user's level will be calculated based on the results of solving the activities, information such as the time it took to complete the activity, the number of mistakes, the number of successes and the scores obtained.

4.6. Teachers, Students

Students are users who experience the virtual environment through different interfaces or input-output devices, which provide the feeling of immersion through visual and auditory feedback.
Elementary students should follow the following process to conduct a game session. The process to carry out a game session consists of six activities, the first one is an interaction activity, it is necessary to log in. The next activity corresponds to the application, it must consult the activities defined by the teachers, when this activity is reached, the previous ones are disabled. The interaction activity called ”selection of options” consists of choosing a task and ”solving tasks” depends on the user interaction. The above two activities are performed sequentially. The management of the game session depends on the application and consists of difficulty management, attention monitoring and score updating. This activity is performed concurrently with the game session. Saving the results is an activity of the application and can only be performed when the information from the previous activities is sent and available.
Teachers participate in the design of the activities that students will have to solve in the virtual environment.

4.7. Virtual Environment

The main objective of implementing virtual reality in education is to support students in understanding abstract concepts. Engaging in immersive experiences increases understanding in the learning process[10]. The virtual environment is mainly composed of a scenario and

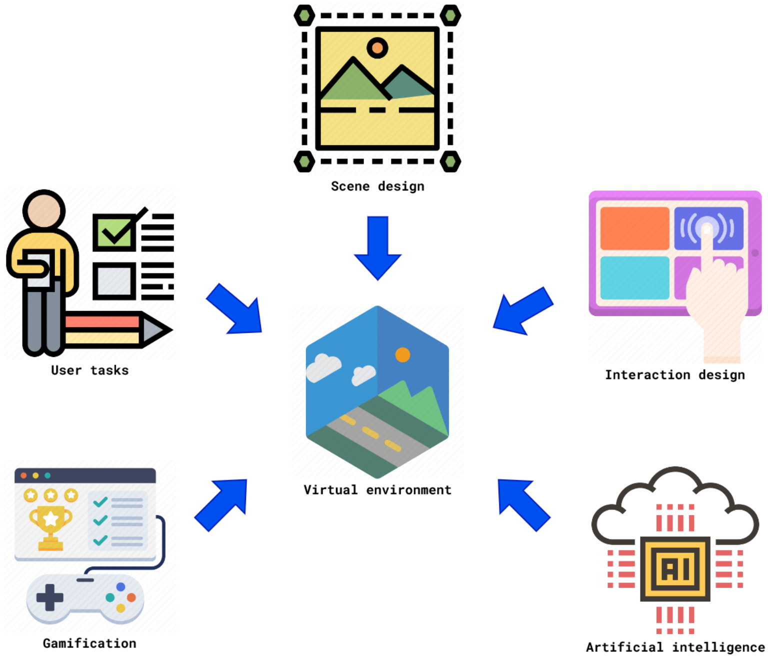

Figure 4: elements of virtual environment.

interactions and is complemented by an artificial intelligence module and user tasks. The design of the scenario and interactions should have a gamification approach.

4.7.1. Gamification

is a strategy to improve activities, systems and others through the creation of experiences similar to those experienced when playing, with the objective of motivating and involving users [16]. In the virtual environment, gamification is applied mainly in the design of scenarios, interactions, and the scoring system in order to generate a pleasant and familiar experience for users.

4.7.2. User tasks

are the main element because they complete the functionality in the virtual environment. User tasks have characteristics such as level of difficulty, expected results, etc.

4.7.3. Stage design

The objective of the scenario design is to provide an experience similar to the one experienced when playing games while solving activities. The design has to focus on the users, in this case, elementary school students. In the scenario design, the objects (3D models) and their appearance are defined. Not all objects will react to user interactions, some will remain static. Only the objects needed to solve the activities will be dynamic and will respond to user interactions.

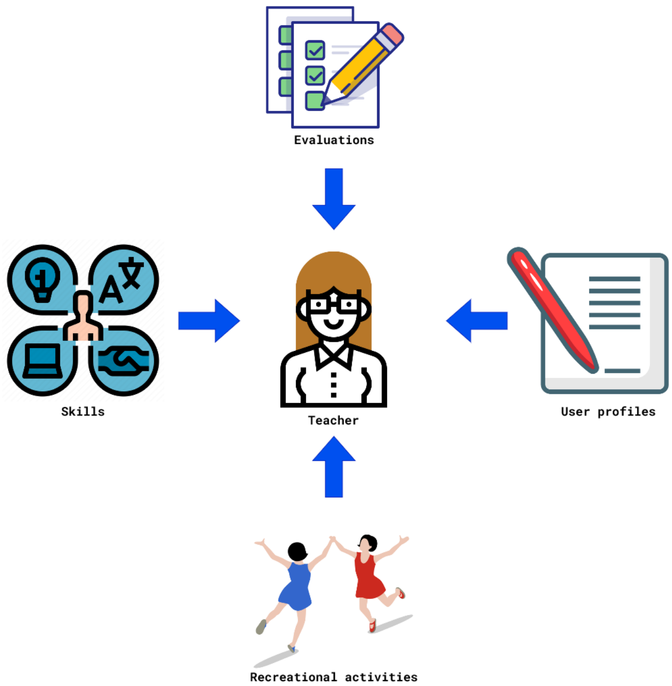

Figure 5: Teachers

4.7.4. Interaction design

Interaction can be defined as an action that occurs between two or more people or objects. In the virtual environment, the actions that users will have to perform in order to interact with the objects arranged in the virtual scenario must be defined. In order to capture the actions of the users and process them into the virtual environment, it is necessary to use interfaces. The interactions must be familiar and easy to use for the users since most of them have not had any interaction with virtual reality environments.

4.7.5. Artificial intelligence (AI)

will be applied in the virtual environment in order to control the difficulty levels of the activities that users must solve. The score obtained by the user in real-time, the time it takes to complete the activity, the number of mistakes, and the number of successes will be used to adjust the difficulty level.
To determine the level of difficulty based on the data collected, different methods can be used. The implementation of a recurrent neural network or the use of an equation that takes the data as parameters and returns the level of difficulty.

4.8. Teachers

4.8.1. Competencies

The basic competencies that a student should obtain in basic education can be divided into three levels: initial, basic and intermediate. The initial level focuses on skills such as spatial-temporal discrimination, and graphic processing of information, while the basic level focuses on skills such as verbal processing of numbers, recognition of numbers and operators, sorting, and seriation. Short and long-term memory skills and arithmetic problems are assessed at the intermediate level.

4.8.2. Recreational activities

Teachers are aware of the recreational activities that can be used to complement traditional education, in this sense teachers have an important role in the choice of interactions that could be used in virtual environments with which students will solve the activities.

4.8.3. User profiles

Teachers perform diagnostic tests to know the knowledge of the students, with the results of the test, a user profile is generated with the general data of the student and the mathematical skills in which it will be necessary to reinforce learning. The student will have a regular education according to the study plans and will also be provided with support through support programs for inclusive education in which they will work with the development of their math skills.

4.8.4. Evaluations

The teacher will apply tests of knowledge of the skills imparted to the students in previous modules, the evaluations can be applied in a traditional way, in VR environments or in a mixed way. When it is identified that the student has acquired such knowledge, the student advances to the next level of skills, all this is done in three different levels until reaching the proposed levels of mathematical skills.

5. Conclusions and future works

The virtual reality ecosystem generated by the architecture can provide the possibility for teachers to design virtual environments by selecting their characteristics. This allows teachers to explore different environments, evaluate the results on the students and choose the environment that achieves the best results on the students. Teachers will be able to teach the same mathematical concept from various approaches, achieving a better evaluation of mathematical skills.

In future work we are working on the implementation of the proposed architecture to generate a prototype and measure the impact or benefits on student learning.

Acknowledgments

Thanks to the developers of ACM consolidated LaTeX styles https://github.com/borisveytsman/acmart and to the developers of Elsevier updated LaTeX templates https://www.ctan.org/tex-archive/macros/latex/contrib/els-cas-templates.

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