Level 2 Augmented Reality System (PokePhy) to Complement Physics Subjects in a Private University in Lima, Peru.

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Abstract

PokePhy is a project that introduces augmented reality into university-level physics education, employing tools like Unity 3D and Vuforia SDK to create an interactive learning experience. By emphasizing speed, time, and distance, the application offers students two difficulty levels (tutorials and quizzes), facilitating active engagement with the subject matter. While demonstrating the potential of augmented reality in higher education, the project also highlights the need for refined user interfaces and considerations for camera quality and lighting conditions. In doing so, "PokePhy" represents an innovative step towards harnessing technology for enhanced learning experiences at the university level.

Keywords

Augmented reality, education, physics, Unity 3D, Vuforia SDK, gamification.

1. Introduction

Augmented reality technology, as part of immersive technologies [1], has a wide range of applications ranging from healthcare, tourism, military, and aviation; however, in education, it has proven to be a great provider of interactive learning and helps to enhance the learning process experience [2]. Its popularity has been increasing in recent years. It was even found that this popularity was similarly distributed in different countries, mainly in primary to university education in other subjects [3]. This shows this tool's great potential and use as a learning enhancer in low-level and university education. Due to the constant difficulty of students to find a better way or technique for learning and the increasing, often worrying, use of devices such as cell phones or digital tablets, mainly in universities [4], it is of utmost importance to find new

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techniques or tools that help students to make educational use of these devices. This can be achieved through augmented reality technology [5].

Specifically, the purpose is to improve the learning experience through a personalized tool and improve and enhance students' cognitive skills. This is because it has been demonstrated that the ability of augmented reality significantly enhances the ability to memorize through gamification [6]. For this reason, it was proposed to develop an application with this critical feature, as it is known that the game of people is a driver of skills and abilities, both physical and mental, which translates into greater creativity and imagination [7]. The vast majority of background on the use of augmented reality in education was done in primary education subjects, with the vast majority of these focusing on capturing children's attention, which differs somewhat from the focus of this research; however, the background presented provides valuable information on the use of augmented reality [8] as a factor with a possible significant impact on learning [9] and capable of enhancing students' problem-based learning through promoting a positive attitude and long-term retention of physics-related topics [10].

One of the investigations used the free tool Aumentaty [11] to generate augmented reality content quickly. The second research created its FenAR [10] application with the Unity 3D platform and the Vuforia SDK. The first of the latter two is a well-known powerful 3D game engine used in conjunction with augmented reality tools to superimpose the virtual on reality and thus create augmented reality applications or games; at the same time, Vuforia is a raised reality software development kit that uses computer vision to detect one-dimensional images or objects and thus place 2D or 3D models on them [12].

The present research used these two tools to develop the application called PokePhy. This application has a user-friendly interface with highly recognizable character images, demonstrating its video game character. The application consists of two levels: easy and complex, the first with simple physics problems and the second with more complex issues closely related to the first mode. These problems were given randomly and tried to complete the classic physics formulas with an invocation of one of the three 3D models. Each model represented a specific dimension, which could be viewed through custom markers.

2. Background

Most of the research related to augmented reality applied in the educational sector focuses on primary education and the development and implementation of applications capable of attracting and improving attention and, therefore, learning in children [13, 14]. However, in the case of university students [15], although not much research was found where augmented reality was applied to teaching, the two precedents show project proposals related to what is aimed to be achieved with PokePhy, in addition to the use of complete tools such as Unity 3D platform and Vuforia SDK. Subsequently, both backgrounds will be described.

The first aimed to develop basic skills in educational technology using mobile devices [16]. This application (shown in Figure 1) was used to work on different skills in critical thinking, comprehensive thinking, and content analysis. Augmented Reality's possibilities are more significant due to the easy manipulation of objects and group teamwork.

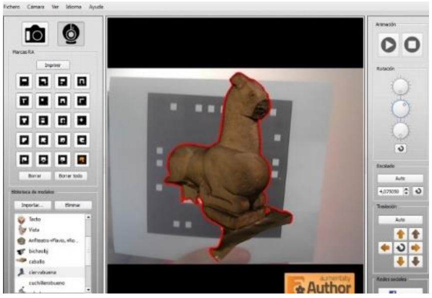

Figure 1. 3D model in Aumentaty author.

In addition, the methodology used is the project method, which was divided into three phases: The first is about the exploration of images through augmented reality with the devices used. The second phase is the collection of information on the art, culture, and society of the pre-Roman peoples. Finally, the third phase identifies the general characteristics of Iberian art by comparing the different works. The subject planned to be taught through the application is Social Sciences in Albacete. The topic touched on in the application is the Iberian art of the same province of Spain. The results were positive because it is an application that runs on a mobile device. It increases the motivation of the students and stimulates an improvement in learning. Through the figures presented in the application, it awakened the interest and curiosity of the students. In addition, now that they are learning, they interactively have fun with the classroom dynamics.

The second background [10] (shown in Figure 2) mainly evaluated the impact of augmented reality technologies on problem-based learning and physics-related topics in seventh graders in northern Turkey. In addition, a final comparison was made between the results of two experimental groups: one group using augmented reality as a tool for problem-based learning and another group using only augmented reality as a tool for problem-based learning. Its methodology consisted of a preparation for the students, that is, dividing them into groups with the characteristics mentioned above. Instructions were given on how each group should behave. Then, an integration between augmented reality technology and problem-based learning was performed (at the stages where it was necessary). Finally, an evaluation was conducted to measure the level of knowledge and their attitude toward physics. Their results showed a highly positive impact of augmented reality technology on problem-based learning. Also, they warned that the non-use of this technology in this context leads to a much lower learning performance.

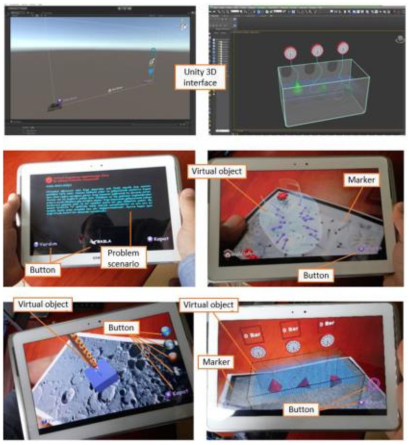

Figure 2. Design of the FenAR application.

3. Methodology

The main objective of active methodologies is always the same: the participation and cooperation of students in the learning process [17]; however, there are many highly widespread in the educational sector, ranging from problem-based or project-based learning to gamification, which will be used in the research [18]. This type of active methodology has been gaining popularity lately because it consists of applying elements and principles of games in a more educational or learning environment to achieve greater motivation and engagement for learners [19]. However, these benefits could be better if we consider what gamification entails, mainly the connection between the player and the game. This indicates that the player should find everything he/she needs efficiently to have a positive relationship with the game [20]. Thus, it is proposed to use the cascade methodology to develop the PokePhy application.

The cascade methodology (illustrated in Figure 3) is a traditional approach to software development that attempts to simulate the designs of other industries. It divides the entire software project into phases, dependent on the previous stage [21]. In this research, the points of this methodology will be followed, describing how the application was realized through the steps of the methodology diagram extracted from another study [22]. It culminates with a test of the functionality where some university students use the PokePhy application to invoke the 3D elements on the customized cards with a nice theme and playability.

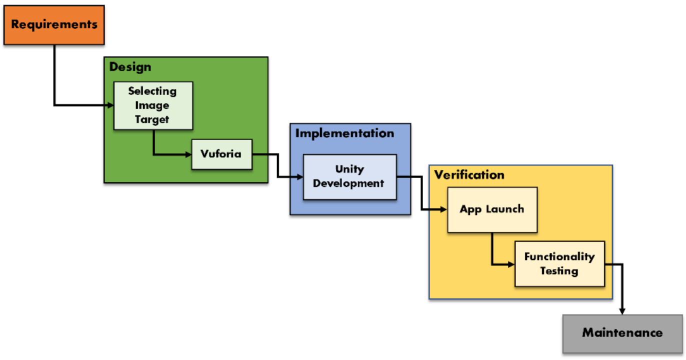

Figure 3. Diagram of cascade methodology.

3.1. Application Requirements

The list of requirements [23] for the system design is shown in Table 1.

Table 1
List of Requirements

Requirements	Description
1	The application will allow young university students to develop cognitive skills like memory.
2	The user will be able to access the application by cell phone.
3	The application can play music, sounds on buttons, and augmented reality interaction.
4	The application will not collect information from its users.
5	The application will not make recordings through the camera.
6	The user can visualize the 3D models through their mobile devices.
7	The application shall have a tutorial section for each of the difficulties.
8	The application shall have two levels of difficulty.
9	The interface design of the application must follow the game's theme.
10	The application shall be compatible with Android devices.

3.2. Selection of Image Target and Multimedia Resources

First, selecting images as markers is essential for the app to scan and display them. The implementation of this process involves utilizing Vuforia Engine and Unity. Images featuring the initial letter of each word in the formulas (e.g., Velocity, Time, and Distance) will be chosen. Subsequently, these images need to be converted to the 24-bit format supported by Vuforia for image recognition. Vuforia Engine, serving as the augmented reality graphics engine software, facilitates the development of the application using this technology. The next step involves adding each selected image to a database in Vuforia (as shown in Figure 4), where a score is assigned, determining the picture's quality.

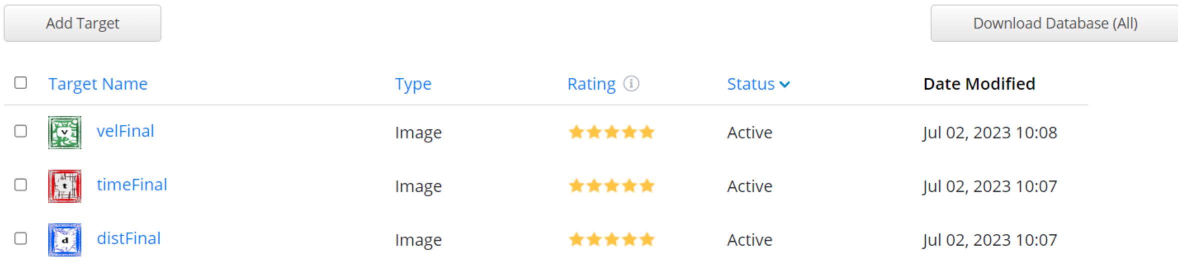

Figure 4. Database of images.

Afterward, the database is downloaded as an installation package (illustrated in Figure 5) for subsequent importation into Unity. In the final steps, Image Targets are added and associated with images compatible with Vuforia. It is imperative to activate Vuforia's AR Camera to leverage the features available in the provided free version.

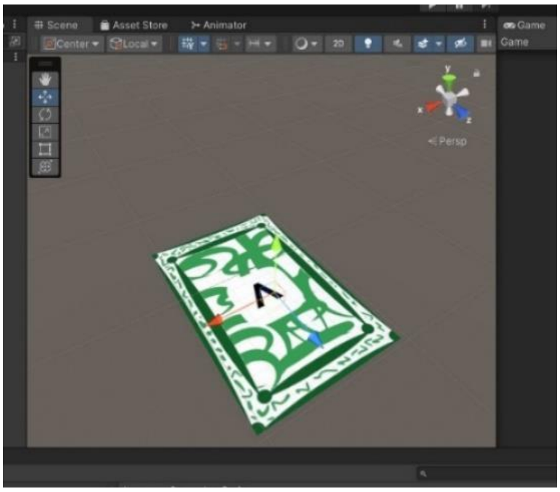

Figure 5. Insert Database of images to Unity.

3.3. Application development in Unity

Starting with creating the user interface using the Canva tool provided by Unity, the screen size will be set to 2196 x 1080. Additionally, integrating the Vuforia augmented reality camera will ensure proper interaction between the image and the 3D model. Regarding the user interface (illustrated in Figure 6), buttons have been designed to facilitate communication between interfaces, enabling the execution of game options within the augmented reality environment.

Figure 6. Development of the application interface in Unity.

An image target of the completed puzzle has been used so that, after solving it, the visualization of a 3D model starts. This model has been animated on the Mixamo page, with many movements stored in a mocap database in BVH format. In this way, the 3D model can be customized. With Mixamo, any character can be animated; then, the model is downloaded and linked to the image (as shown in Figure 7).

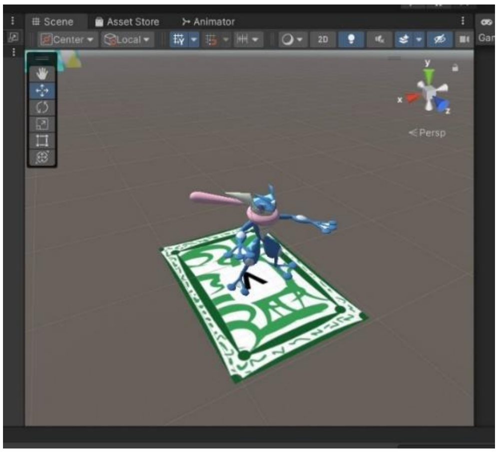

Figure 7. Implement the 3D model and videos to the image targets.

3.4. Functional description

Regarding functionality, the project has been designed intuitively, with each part of the application serving a purpose in teaching this Physics topic, which involves speed, time, and distance. Regardless of the user's characteristics, they can learn about the subject by following a sequence and making decisions as it suits them.

The first thing users can do when they run the application is access the tutorials that are part of this physics learning experience. These tutorials include formulas encompassing previously mentioned concepts, ranging from foundational knowledge to slightly more complex equations. Following this, they can choose one of the two available game modes: easy and hard. Both game modes open an augmented reality experience where they can use external cards containing one of the concepts to respond to the presented equations, thus reinforcing their understanding of the formulas.

Users should start in accessible mode and wish to increase the difficulty level. They can switch to hard mode by using an available button. In both ways, they can view their score once they complete all the grades available for that game mode.

3.5. User Interface Description

Describing and presenting an overview of the application's interface (illustrated in Figure 8). The interface has been designed to be colorful and aligned with the concepts it aims to teach. It focuses explicitly on learning physics, particularly the basic formulas for Uniform Rectilinear Motion (URM) and Uniformly Accelerated Linear Motion (UARM). Therefore, the application's background consists of an animated image in green and blue colors and a looping melody. Upon launching it, you can see the presentation of the program used for its creation. In this case, it is Unity. Following this, the application will request the necessary permissions to access the device's camera each time it is run.

Once permissions are granted, you can see the start of the main interface, which includes the application's name, an image of a Poke ball, and a Pokémon representing the game's central theme. The user should click on the image of the Poke ball to access the application's main menu, where four buttons of different colors can be seen, along with an animation of more Pokémon. These four buttons consist of two game modes and two tutorials.

In Tutorial 1, you can see the types of Pokémon corresponding to each concept being studied, such as distance, speed, and time. It is even possible for the user to click on each Pokémon to hear its characteristic associated sound, which will also be heard during augmented reality. The user can return to the main menu using the back arrow button. Tutorial 2 presents a more advanced level of these concepts, including various formulas that use them and their results. This page also includes a back arrow button that allows returning to the main menu.

Moving on to the game modes, the user can choose between the easy manner and the problematic mode. In an accessible way, the application will open the device's camera, and the user will be able to see the score increasing or decreasing in the corners and the number of levels completed, up to six. Additionally, the application will generate a fundamental problem using the previously mentioned concepts. The user should focus on cards representing distance, speed, and time as a response to the equation presented. This will also display the corresponding Pokémon for each term as an augmented reality image, aiding in better memorizing these formulas. Once the six rounds are completed, the game will show a game over, indicating it's finished.

In the challenging game mode, the user will perform the same action but using equations (seen in Tutorial 2) with a higher difficulty level. Similarly, once seven rounds are completed, the game will end.

Figure 8. Start of the PokePhy application, own creation.

3.6. Functionality tests.

To provide more specific details about the functionality tests, it's essential to highlight that the application focuses on formulas related to Uniform Rectilinear Motion (URM) and Uniformly Accelerated Linear Motion (UARM) in physics. This encompasses fundamental concepts like speed, distance, and time. The functionality tests, conducted with a sample of 50 university students in the third and fourth cycles of Physics I, aimed to evaluate the application's effectiveness.

Participants were divided into two groups, one using the accessible mode and the other using the hard way. The entire testing process, including explaining the application's function and the subsequent division into groups, was meticulously recorded for accuracy and transparency. The students' engagement and feedback were instrumental in assessing the application's impact on reinforcing their understanding of physics concepts.

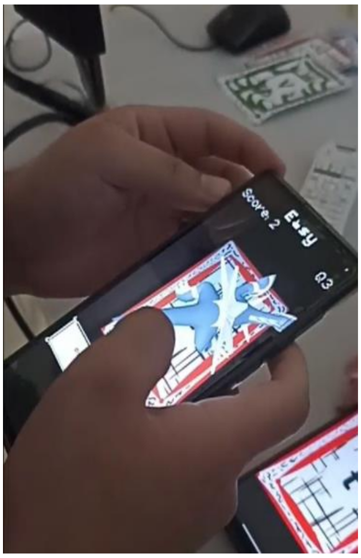

Figure 9. Students solve the problems in accessible mode.

The functional tests involved virtual materials, including the application and image cards for projecting 3D models. The students worked in pairs, one using the application and the other managing the cards, creating a comfortable and collaborative learning environment.

Figure 10. Students using Pokephy's interface.

Despite the initial challenges with tutorial clarity, students quickly adapted to the application after more thorough interaction. The tutorial, gameplay buttons, and added images for a visually appealing user interface contributed to a positive experience.

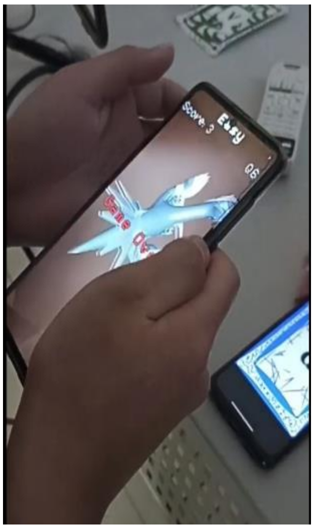

Figure 11. Despite showing the correct answer, the game finished because of the camera.

During the game, students demonstrated satisfaction when correctly answering questions, although challenges arose, such as the camera's difficulty in detecting cards, often attributed to lighting conditions. Some expressed initial confusion with the games, but their discomfort diminished as they became more familiar with the application through continued interaction.

4. Conclusions

In conclusion, augmented reality is a valuable tool that significantly enhances students' learning experiences. By integrating augmented reality into education, as evidenced by the "PokePhy" project, the understanding of concepts can be improved, and active student participation in the learning process can be encouraged. Moreover, augmented reality can be applied across various educational domains, particularly in higher education, making it a versatile and practical tool for educators.

Continued research and development of new applications for augmented reality in education are crucial to further enhancing teaching quality. Having a clear purpose for using augmented reality in education, addressing students' challenges in the learning process, and exploring the possibilities augmented reality offers can collectively elevate the quality of education. Utilizing tools like Unity 3D and Vuforia SDK demonstrates a commitment to harnessing advanced technology for educational benefits.

However, the project also highlights some important considerations. The need for improved user interface design and the impact of camera quality and lighting conditions on the augmented reality experience underscores the importance of refining the application's usability. These challenges can be overcome through iterative development and close attention to user feedback, ultimately paving the way for augmented reality to play a more prominent role in enriching the educational journey for university students. As technology continues to evolve, the "PokePhy" project exemplifies the innovative spirit that seeks to unlock the vast potential of augmented reality in higher education, offering a promising path forward for educators and learners alike.

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