New Technologies and Opportunities: Exploring the Potential of Video Games in Education

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Abstract

The incorporation of video games as a learning method in educational settings offers an innovative approach to enhancing student engagement and knowledge retention. This paper investigates the effectiveness of video games in education, focusing on their role in reinforcing learning outcomes across various age groups and subjects. Utilizing a mixed-methods approach, which includes audiovisual elements, the study combines quantitative data from standardized test scores with qualitative feedback from educators and students. Findings suggest that strategically aligned video games with curricular objectives can significantly enhance students' understanding and application of concepts. The study also underscores the need for careful selection and adaptation of video games to meet educational goals and student needs. Despite challenges in integration and assessment, the overall impact of video games in education is seen as positive, fostering a more engaging and dynamic learning environment. This research highlights the potential of video games as a complementary educational tool, advocating for further exploration of their long-term effects on learning and motivation, especially in complex subjects that pose teaching challenges.

Keywords: Educational Video Games, Educational Technology, Learning Outcomes, Academic Commitment, Interactive Learning

1. Introduction

Technological advancement has led to a significant evolution in the educational field, opening doors to innovative teaching and learning methods. In this context, the present study, titled 'New Technologies and Opportunities: Exploring the Potential of Video Games in Education', delves into the analysis of how video games, a popular form of entertainment, can be transformed into powerful pedagogical tools. This research specifically examines the integration of an educational game developed in Unity 3D Engine, focused on the solar system, for secondary education students. The goal is to investigate whether this modern approach to learning enhances knowledge retention, motivation, and student engagement.

In recent years, there has been growing interest in the application of video games in educational settings, driven by the need to address diverse student learning styles and increase their engagement with educational material. Video games offer an interactive and engaging learning experience, which can be particularly effective for younger generations accustomed to digital technology and interactive media. This mode of learning has shown promise in various studies, such as the one conducted by Mawas et al. (2020), which investigated the impact of a 3D educational game based on the solar system for elementary students. This study found that students who used the game showed significant improvement in performance compared to a control group, highlighting the positive learning experience provided by the educational game 'Final Frontier' [1].

The growing evidence suggests that video games can be an effective tool for enhancing learning across various subjects, especially in those where visual evidence is lacking. They can be particularly effective when aligned with curricular objectives and tailored to the specific needs of students. Moreover, video games offer the opportunity to experience learning in a more engaging and less traditional manner, which can be crucial for capturing students' attention in an increasingly technology-dominated world.

With this study, we aim to contribute to the understanding of the role of video games in education, assessing their effectiveness as a learning tool in a formal educational context. By doing so, we hope to shed light on how they can be effectively incorporated into the school curriculum to improve both student engagement and learning outcomes, responding to the research questions developed prior to this study: Does a simple spaceship game with a simulated Solar System work for learning about gravitation and the morphology of the Solar System? ¿Do interactive digital environments work for learning? ¿Is this the future of the education?
These are important questions for the development of this research that will be addressed during the study in order to clarify all of them as much as possible.

2. Related Work

Currently, there has been an increase in research in this area due to the need and attempt to adapt in order to provide an effective motivational boost to the social changes being brought about by new technologies and social restrictions caused by COVID-19. This idea (AVeR) was proposed and developed in 2017 by the 'Desafío STEM' initiative of the Movistar group, in which a group of high school students, supported by the Aragonese company Imascono, presented several models of digital learning on the Unity 3D engine in VR, with the aim of graphically teaching parts of the university entrance exam syllabus, specifically the formation of the aurora borealis and historical information and details of the Pantheon of Agrippa.

The integration of video games in education is the subject of numerous studies, which have examined their effectiveness and design methodologies from various perspectives. For example, Sun and Gao (2015) [2] explored active educational video games, finding that these games not only improved children's scientific knowledge, but also significantly increased their motivation and level of physical activity. This finding is particularly relevant, as it suggests that incorporating physical elements into video games can directly enrich the educational experience [2]. On the other hand, Galanina and Vetushinskiy (2019) focused on the use of both commercial and educational video games to teach philosophy, highlighting the importance of balance between gameplay and instructional design to maintain motivation and active student engagement throughout the process [2]. This balance is crucial to ensure that video games are not only attractive, but also effective as interactive learning tools. It is a risky challenge to maintain a positive balance throughout the playable time, so the game design can modify the slope of this balance [2].

In the field of computer science education, López-Fernández et al. (2021) provided evidence that game-based learning using educational video games created by teachers is as effective, if not more so, than traditional teaching in terms of knowledge acquisition. Moreover, they discovered [4] that this approach was exceptionally successful in increasing student motivation in order to address the serious student failure present in Spanish students.

Additionally, an important advancement was made by Martínez et al. (2022), where they conducted a systematic review on the effect of entertainment video games on academic learning. Their findings indicated that these video games can be effective educational tools in almost all academic disciplines, especially in foreign languages and sciences [5]. This study highlights the versatility of video games as educational tools in a variety of academic contexts, focusing on how to present narrative elements in the digital learning environment in order to maintain that balance [2] in its ideal position.

Finally, an important point in our research was the study of interfaces [7]. Regarding the design of interfaces for educational video games, Ozcelik et al. (2010) investigated how the strategic placement of informative elements, such as in the top right corner of the screen, can enhance users' retention and processing of information. This study is especially relevant for the design of educational video game interfaces, as it suggests that the location and design of elements on the screen can have a significant impact on the effectiveness of each player's learning experience.

These studies provide a comprehensive understanding of how video games can be effectively utilized in digitalized education and the development of the best methodology to carry it out, highlighting the importance of careful design that balances gameplay with educational objectives, and the need to consider the user interface and the placement of informative elements to enhance the experience of the process while maintaining an optimal balance [2] in order to fit all the pieces of a puzzle together and achieve a good interactive design capable of conveying information.

3. Methods and Materials

This study details the transformation and adaptation of an existing game into an innovative educational tool focused on teaching astronomy through an interactive gaming experience. Using Unity, version 2021.3.25f1, as our development platform, we have created a simulation environment that not only captures the interest of players but also facilitates learning about space-related topics. Throughout this section, we will explore in detail the processes and materials used, from adapting the original game to implementing evaluation methods and data collection. This methodological approach combines technical and pedagogical aspects to ensure an effective and engaging educational experience while gathering significant data to assess the game's impact on user learning.

3.1. Contextualization of the Game in Unity 3D Engine.

The game was developed using Unity 2021.3.25f1, a choice that allowed us to fully leverage its simulation and rendering capabilities to create an interactive and immersive space environment. This platform has been crucial in adapting the game to meet our pedagogical objectives, effectively integrating educational content into the game mechanics. Going deeper into the use of Unity, it is noteworthy how it has facilitated the creation of a visually stunning environment that not only captures users' attention but also provides the necessary means to conduct this research. The versatility of Unity has been essential in adapting the game, making it not only visually appealing but also enriching it with educational content, showcasing its ability to create interactive and engaging learning spaces.

3.2. Game Contextualization

The game is set in an interactive space context, blending traditional gameplay mechanics with educational elements. Players take control of a spaceship, carrying out missions that involve approaching specific targets, whether they are planets within the solar system or satellites, culminating in a final mission at the Sun. In total, the game comprises 13 different missions.

As players approach their target in each mission, they are presented with a panel containing detailed information about the planet or satellite they are approaching. This educational panel is an integral part of the game, providing players with the knowledge necessary to correctly answer the test that follows each mission. The presentation of this information is designed to encourage incidental learning, making use of the approach time to impart basic astronomical knowledge effectively and engagingly.

In addition to the educational elements, the game incorporates additional mechanics to enhance fun and challenge. Players must maneuver through asteroids, destroying them to avoid damaging the ship and losing health. They can also collect stars to accumulate points, which can be used to improve various aspects of the ship such as acceleration, heat management, thrust speed, ship health, and overall speed. These additional features not only enrich the gaming experience but also provide an additional level of engagement and challenge for players.

3.3. Adaptation of the Game for Educational Purposes

In this section, we will address how the original game was transformed into an educational tool. The adaptation process involved modifying both the game mechanics and its content to facilitate learning without compromising player entertainment and engagement.

3.3.1 Modification of Game Mechanics:

To ensure that players could focus on the educational panels, it was necessary to adjust the game's difficulty. This was achieved by reducing the number of asteroids and eliminating instant collisions of the ship with planets, which previously would restart the game. These changes helped maintain a balance between challenge and learning opportunities.

3.3.2 Incorporation of Educational Content:

A crucial part of the adaptation was the integration of educational elements. An informative panel system was added during missions, providing relevant data about planets and satellites. To reinforce learning, each mission concludes with a test based on the presented information. This approach not only makes learning interactive but also contextual, linking astronomical knowledge directly to the gaming experience.

3.3.3 Generation of Data for Learning Assessment:

Another significant innovation was the implementation of a system to generate CSV files with user responses to the tests. This system allows for a detailed analysis of the game's effectiveness as an educational tool, evaluating both knowledge retention and user gaming experience.

3.4. Mission Design and Integrated Assessments

In this section, we detail the mission design and how educational content is organically and coherently integrated. Each mission focuses on a specific astronomical object, with a dedicated information panel providing relevant data about that object. For example, in the mission related to Earth, a panel with specific information about this planet is presented (see Figure 1 for a representation of the Earth's information panel).

Figure 1: Earth educative panel information

3.4.1 Information Consistency:

Consistency is a key factor in our educational approach. In each mission, the information panel is consistent and specific to the mission's objective. If the mission is to explore Mars, all the information on the panel will be exclusively related to Mars, ensuring that players can clearly relate the information to its context.

3.4.2 Assessment with Random Single Question:

At the end of each mission, players face an assessment test designed to measure their understanding of the learned content. This test consists of a single question, randomly chosen from a set of 4 to 10 questions specific to that mission. The random selection of the question ensures that each assessment experience is unique, providing continuous challenge and encouraging retention and effective application of acquired knowledge. By focusing on a single question per test, we ensure a focus on the quality and relevance of the content rather than quantity.

3.4.3 Implementation of Question Selection System:

Figure 2 presents a snippet of the code used to select questions related to the Earth mission. This code snippet illustrates how randomness and question selection are handled, ensuring that each test is both relevant to the mission and varied in its focus.

```
case "Earth":
    questionIndex = UnityEngine.Random.Range(1, 10);
    switch (questionIndex)
    {
        case 1:
            question = "What is the radius of Earth?";
            answerA = "6,378 KMs";
            answerB = "3,959 KMs";
            answerC = "6,851 KMs";
            answerD = "2,439 KMs";
            correctAnswer = 1;
            reason = "Earth is the fourth smallest planet in the Solar System";
            break;
        case 2:
            question = "Does Earth have any artificial satellites?";
            answerA = "No";
            answerB = "Yes, One";
            answerC = "Yes, Two";
            answerD = "Yes, More than Two";
            correctAnswer = 2;
            reason = "Earth has one artificial satellite";
            break;
        case 3:
            question = "How many natural moons does Earth have?";
            answerA = "Two";
            answerB = "None";
            answerC = "One";
            answerD = "Three";
            correctAnswer = 3;
            reason = "Earth has one natural satellite, the Moon";
            break;
        case 4:
            question = "What is the primary component of Earth's atmosphere?";
            answerA = "Oxygen";
            answerB = "Carbon Dioxide";
            answerC = "Nitrogen";
            answerD = "Hydrogen";
            correctAnswer = 3;
            reason = "Around 78% of Earth's atmosphere is nitrogen";
            break;
```

Figure 2: Code for random question selection for Earth task question

3.4.4 Example Test Questions:

The test questions in each mission are meticulously designed to assess the player's understanding of the presented astronomical content. These questions vary, but each aims to reinforce the learning acquired during the corresponding mission.

3.4.5 Answers and Feedback:

Figures 3 and 4 exemplify incorrect and correct responses in the tests, respectively. Figure 3 illustrates an incorrect response followed by specific feedback that helps the player understand the error. On the other hand, Figure 4 shows a correct response, confirming the proper assimilation of knowledge.

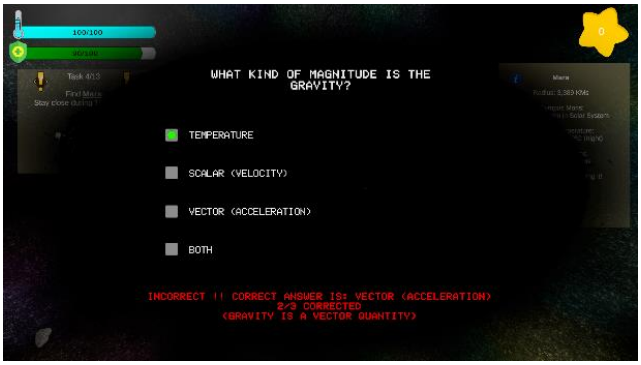

Figure 3: Answer answered incorrectly.

Figure 4: Answer answered correctly.

3.4.6 Post-Response Internalization Period:

After answering the test question, a 15-second period is provided where the game pauses, allowing the player to reflect on and internalize the learned content. This brief interval is crucial for reinforcing learning, offering a moment of introspection and information consolidation, whether by correcting an error or reaffirming a correctly understood concept.

3.5. Technological Implementation and Data Collection

In this section, we describe the technological infrastructure used for game implementation and data collection. This infrastructure is essential for evaluating the game's effectiveness as an educational tool and for tracking player progress and understanding.

3.5.1 Tracking and Data Collection System:

We have developed a tracking system that records player responses in CSV files. This system is essential for collecting data that allows for a detailed and objective analysis of the educational impact of the game.

3.5.2 Generation of CSV Files:

Figure 5 shows a snippet of the code used for generating these CSV files. This code illustrates how player responses are saved and stored, along with user identification and the correlation of their responses with the correct ones.

```
1 referencia
void GenerateCSV()
{
    StringBuilder csv = new StringBuilder();

    string directoryPath = Path.GetDirectoryName(Application.dataPath);
    string filePath = Path.Combine(directoryPath, "QuestionData.csv");

    bool fileExists = File.Exists(filePath);

    if (!fileExists)
    {
        csv.AppendLine("User ID,User Answer,Correct Answer");
    }

    for (int i = 0; i < arrayUserAnswers.Length; i++)
    {
        csv.AppendLine($"{gameManager.currentUserID},{arrayUserAnswers[i]},{arrayCorrectAnswers[i]}");
    }

    if (!fileExists)
    {
        File.WriteAllText(filePath, csv.ToString());
    }
    else
    {
        File.AppendAllText(filePath, csv.ToString());
    }

    Debug.Log("CSV generated in " + filePath);
}
```

Figure 5: Code fragment to file CSV generation

3.5.3 Structure of the Collected Data:

Figure 6 provides an example of the generated CSV file. This file includes three main columns: 'User ID,' which identifies the player; 'User Answer,' which records the response given by the player to a specific question; and 'Correct Answer,' which indicates the correct answer to that question. This structure allows for a clear evaluation of whether the players' responses are correct or incorrect.

	A	B	C
1	User ID	User Answer	Correct Answer
2	1	2	1
3	1	3	3
4	1	1	1
5	1	2	2
6	1	1	1
7	1	2	2
8	1	4	4
9	1	1	1
10	1	1	2
11	1	1	1
12	1	3	3
13	1	2	1
14	1	1	4

Figure 6: CSV file attributes to process

4. Results

The results derived from the implementation of the educational game, developed using Unity 3D Engine and focused on the solar system, reveal significant improvements in knowledge retention and motivation among Secondary Education (ESO) students. This game, which integrates interactive elements with educational content, has provided students with a dynamic and engaging platform to explore and learn about the solar system.

To evaluate these results, data obtained through a CSV file generated by the game was processed. The study involved seven university students majoring in Computer Engineering and Game Design and Development, as well as nine 4th-grade ESO students. The latter participated in multiple gaming sessions, allowing for a detailed analysis of the impact on their learning and motivation.

4.1. Learning and Retention

The analysis of data obtained through the tracking system for each player indicates a substantial improvement in students' knowledge of astronomical concepts covered at the 4th-grade ESO level. This conclusion is based on the correct answers provided in the exams conducted after each educational mission. The data, collected and examined through the CSV file, not only demonstrates active engagement by students with the educational material but also effective understanding and retention of the presented content.

4.2. Motivation and Engagement

The integration of challenging gameplay mechanics, combined with carefully selected educational elements, has proven to be an effective strategy for keeping students motivated and engaged with the learning material. In our study, we have observed that game design, especially the way information is presented during missions, is crucial in achieving an optimal balance between learning and entertainment. This includes interface design, data selection, as well as the design and harmony of the three-dimensional

space. This harmonization ensures that students not only have fun but also acquire knowledge effectively.

One of the distinctive features of our game is the incorporation of constant challenges after completing a mission that can be a difficult task for some people, requiring the application of specific knowledge. For example, to progress in certain stages of the game, students must solve problems or answer questions related to the curriculum. Furthermore, to reach these stages, they must improve their own spaceship or strategize based on the translational movement around the Sun. This interactive methodology promotes participation and deep learning since students must apply what they have learned in a practical and stimulating context.

Additionally, the game's narrative and visual and auditory elements have been designed to attract and maintain the students' interest. It is essential to find a suitable color palette that focuses the player on the important aspects throughout the gameplay, in addition to receiving auditory feedback at every moment.

The most significant challenge in this study has been the selection and analysis of relevant data, given the extensive educational curriculum, it was necessary to focus on the most relevant aspects for our study's objective: the impact on the learning and motivation of teenagers. This approach required a delicate balance between gameplay mechanics and academic performance throughout the gaming experience. By constantly monitoring concentration, motivation, and commitment of the students, we were able to gain a deeper understanding of how the game influences their learning and attitude towards educational material.

Preliminary results are promising and suggest that gamification can be a powerful tool in the educational environment, especially for younger generations accustomed to digital interaction and visual media. However, it is important to continue exploring and refining these strategies to maximize their effectiveness and ensure they adapt to a wide range of learning styles and educational needs.

4.3. Evaluation of Effectiveness

The structure of the collected data has allowed for a clear evaluation of the game's effectiveness as an educational tool. Consistency in the presentation of information and assessment through a single random question at the end of each mission has provided an effective method for measuring understanding and retention of knowledge, detailing the reasons for success and failure, and providing feedback for each one that reinforces knowledge for the next questions or rounds.

The most important aspect, as we have already mentioned, is balance, maintaining a constant or even positive balance that demonstrates effectiveness, which we will discuss further (Figure 8).

4.4. Evaluation of Learning and Player Performance

The analysis of the provided graphs reveals clear trends in terms of knowledge retention and improvement in player performance over time.

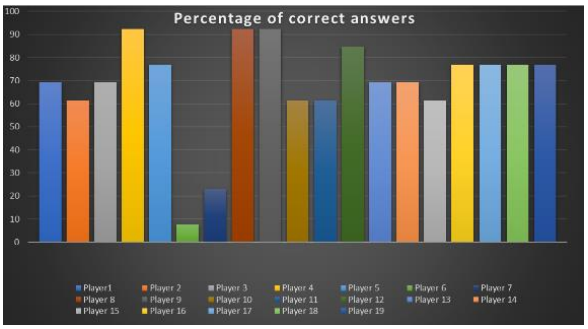

Figure 6: Diagram of the percentage of correct answers from each player.

The first graph (Figure 6) displays the percentage of correct answers obtained by each player. Significant variability is observed among the participants, reflecting notable differences in their comprehension and retention of the educational content delivered through the game. While some players achieve success rates close to 90%, others exhibit considerably lower rates, even considering that they have only played once. This disparity in results suggests areas of opportunity for improving both the game's difficulty and the strategies for presenting educational content.

One possible explanation for this variability could be related to individual differences in learning styles and prior experience with similar games. Additionally, factors such as attention, motivation, and the gaming environment could influence players' performance. For example, those more familiar with interactive games might find it easier to navigate and understand the game mechanics, which could, in turn, enhance their performance.

In future versions of the game, the implementation of an adaptive system that adjusts the difficulty and method of presenting information based on the player's responses and progress could be considered. This would not only personalize the learning experience for each student but could also help minimize performance disparities. Furthermore, conducting a deeper analysis of response patterns would be beneficial, as it could reveal insights into specific areas of content that are more challenging or confusing for students.

These findings underscore the importance of an educational game design that is not only interactive and engaging but also flexible and adaptive to individual learning needs. Continuous evaluation and adjustment of the game, based on empirical data and user feedback, will be essential to maximize its effectiveness as an educational tool.

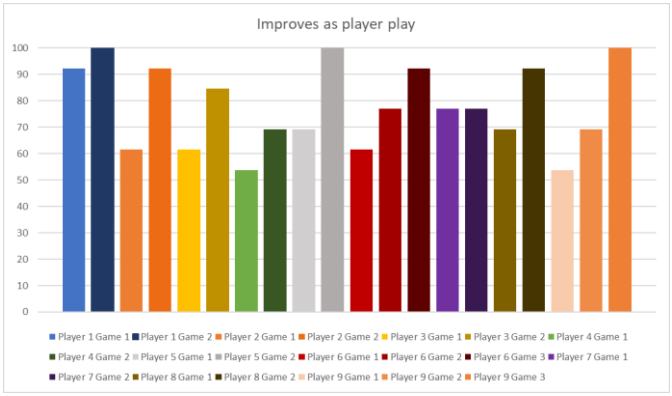

Figure 7: Diagram of the percentage of correct answers for each player in each game played.

The second graph (Figure 7) reflects the improvement in the percentage of correct answers for each player over several games, showing in the same color range the evolution of each game for each player. This upward trend indicates that the game not only captures the players' interest but also reinforces learning as players become familiar with the content. It is notable that for most players, the improvement is consistent, suggesting that the game's design is effective in teaching basic educational concepts to teenagers through repetition and positive reinforcement. However, there are varying degrees of improvement, suggesting that the design of the learning game can be improved to achieve a steeper slope.

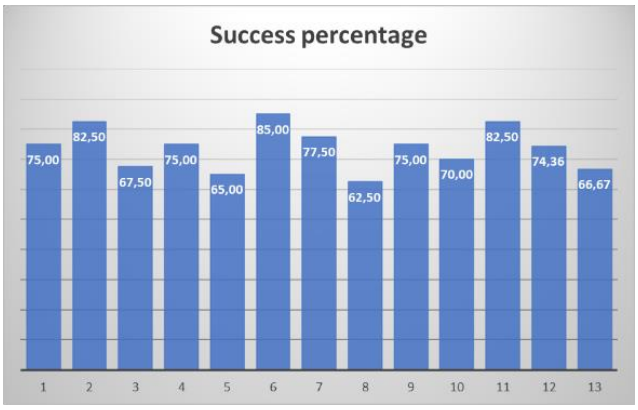

Figure 8: Diagram of the percentage of correct answers for each question.

The following graph (Figure 8) presents the success percentage per question, allowing us to evaluate which concepts have been assimilated more effectively and which ones require a revision in how they are presented in the game. Questions with lower success percentages could indicate areas where the educational content needs to be clearer or where the game could provide more detailed feedback. Furthermore, we can see that there is not a significant variation in the questions, and the player remains motivated throughout the game, showing that our study has a correct balance that has been adapted thanks to experts in the field of computer science and video games through their "Testing Forms."

4.5. Feedback and Improvements

The responses to the tests and the feedback provided have been essential in the educational process. The post-response internalization period has reinforced learning, offering students the opportunity to reflect on the knowledge acquired.

In conclusion, the educational game has proven to be an effective tool for teaching basic astronomy, improving both knowledge retention and student motivation and engagement. The results support the integration of video games in educational environments, strategically aligning them with curriculum objectives and adapting them to the needs of students.

The results indicate that the educational game in Unity: Air Education has succeeded in improving knowledge retention and student motivation, as evidenced by the improvement in correct answers throughout the games. Furthermore, the game provides an effective platform for identifying and addressing specific areas where students may have difficulties. Adapting the content and game mechanics based on these results could further enhance the educational experience and student performance.

These results reaffirm the importance of educational video games as complementary tools in learning, as they demonstrate a positive trend in improving student performance and knowledge acquisition through interactivity and engagement, especially in abstract areas. This is why most studies are based on environments that are not easily accessible.

5. Discussion and Conclusions

The study highlights the significant potential of educational video games in the field of learning, revealing that these are not merely entertainment tools but powerful means for education. The studies analyzed in this work provide a detailed understanding of how these games can be effectively used in various educational contexts.

One of the most significant contributions of educational video games is their ability to increase student motivation [4][1][3], striking a perfect balance [2]. The immersive and engaging digital environments of these games capture students' attention, facilitating deeper engagement with educational content. This enhanced motivation not only improves knowledge retention but also fosters a positive attitude towards learning and a desire to learn.

Educational video games have a wide range of applicability [2][6], from secondary school students to university levels and for different subjects, such as philosophy [3] or exact sciences. They can be especially valuable in fields like physical sciences, where abstract concepts are often challenging to understand through traditional teaching methods, which tend to have lower

performance. By visualizing these concepts in an interactive and engaging format, video games can facilitate better understanding and appreciation of the material. Furthermore, they can improve performance compared to traditional and outdated methods [9], where results are often quite negative. Looking ahead, educational video games have the potential to revolutionize the educational landscape. With the advancement of technology [8][5] and a better understanding of game design methodologies, these resources can become increasingly personalized and tailored to individual learning needs [1], offering experiences that are both educational and deeply engaging. The technological evolution in game design and three-dimensional environments opens up a world of possibilities in the academic field, and we believe it should be leveraged.

In conclusion, educational video games not only enrich the learning experience but also prepare students to tackle complex challenges in the academic world and beyond by adapting to a digital future and improving their knowledge in this area. This study underscores the importance of integrating these games into educational curricula to fully harness their potential in developing critical skills and student motivation in digital environments, ultimately contributing to the improvement of the education system and reducing dropout rates.

Acknowledgments

We would like to express our gratitude to all the teachers of game design who have provided us with a powerful tool to conduct this research. We also extend our appreciation to our study participants for their time and feedback, experts for their valuable.

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Appendix A: Game Download Link

For a hands-on experience with the educational game analyzed in this study, 'Air Education,' readers can access the following download link:

Executable dowload link