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The Effects of Gamification in Space Exploration Learning

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ABSTRACT

Gamification in education has grown in popularity in recent years. However, gamification in space exploration education receives limited attention. This paper introduces Mission to the Star, an innovative online learning platform designed for primary students, immersing them in the fascinating journey of NASA's Parker Solar Probe as it ventures closer to the Sun. Embarking on an extraordinary mission, players assume the role of a spacecraft and navigate toward the Sun's atmosphere, learning vital information along the way. Research findings demonstrate that the incorporation of gamification elements such as badges, score points, certificates, leaderboards, and more, has notably enhanced student learning in comprehending the Parker Solar Probe mission. By integrating these gamified elements, students are motivated to actively participate, benefiting from an interactive and enjoyable learning experience. Mission to the Star holds significance in education as it provides an interactive exploration encounter that sparks the curiosity and enthusiasm of young learners toward space exploration and science knowledge.

1. Introduction

Gamification, a modern learning approach has garnered attention for its potential to spark space science education. Many studies have explored its effectiveness in enhancing the learning experience [1-4]. Gamification creates high engagement levels among learners and is particularly relevant in educational contexts [5-7]. This approach is not limited to specific age groups and has proven effective for various academic levels [8]. Gamified learning platforms incorporate elements such as point systems, certifications, collectible items, power-ups, leaderboards, and user progress tracking [9]. These features transform conventional educational methods into captivating and interactive experiences.

The gamification approach empowers educators to build stronger collaboration and interaction among students and teachers [10-13]. The approach facilitates two-way communication in classroom settings. Teachers can introduce gamified learning platforms with features such as lesson

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modules, progressive levels, and progress monitoring. This gamified platform makes lessons more engaging and effective than traditional textbook-based methods [14]. Furthermore, gamification creates a direct and exciting connection between the learning platform and students [15]. In the case of programming platforms like CodeCombat [16], students can immediately apply their knowledge to solve real-world problems and enhance memory retention. The platform offers instant feedback on answers and knowledge, reinforcing learning and enabling students to reflect on their responses [17].

Additionally, gamification can instil a sense of enjoyment and positive addictiveness, promoting stress-free learning environments and improving student knowledge retention [18]. Beyond the advantages within the classroom, gamification holds the potential for fostering awareness of space science [19]. Learning about missions like Parker Solar Probe [20] not only imparts knowledge but also ignites interest in space exploration. In Malaysia, space science is introduced to primary school children as young as nine years old (Primary 3). Notable achievements, such as sending the first Malaysian Astronaut, Dato' Dr. Sheikh Muszaphar Shukor Al Masrie bin Sheikh Mustapha, into space, have sparked interest. However, the curriculum's coverage of space exploration remains superficial [21]. Parker Solar Probe's mission offers an opportunity to significantly enhance students' comprehension of space science [22]. According to the previous study [22], space with its boundless mysteries and vital role in technologies is worth exploring.

Furthermore, educational programs such as the Kerbal Space Program [23], empower young learners by allowing them to construct and launch spacecrafts, fuelling their curiosity and practical knowledge. By integrating gamified elements and fostering awareness of the solar system [24], educators can inspire students, elevate their understanding of space, and trigger curiosity about the mysteries of the universe. However, limited studies explored the use of gamification to improve student learning about NASA's Parker Solar Probe. In addition, the motivation for this work stems from the current education system, where traditional teaching methods often struggle to engage students, particularly in complex science subjects like space exploration. These traditional approaches may not align with the preferences of today's younger generation. There are challenges and opportunities associated with integrating gamification into the learning process [25]. In addition, the literature shows a knowledge gap related to the effect of using gamification to enhance space exploration knowledge [19]. Hence, this study aims to determine the impact of gamification in space exploration learning, the incredibly fascinating journey of NASA's Parker Solar Probe.

2. Methodology

2.1 Establishment of Gamified Space Exploration

The Agile methodology was deliberately selected in this study due to its iterative nature, which facilitates the continuous discovery and development of an effective gamification solution. This adaptable methodology is known for its ability to deliver rapid results and establish measurable milestones. Furthermore, Agile methodology allows for an incremental and iterative process, fostering direct engagement with students and immediate feedback collection. These feedback loops are instrumental in ensuring that the gamification elements seamlessly integrated into the learning platform align meticulously with the expectations and requisites of the students. This methodology not only assures the effective integration of gamification but also enables ongoing refinement of these elements to optimize their impact on student engagement and knowledge retention.

Considering the gamified space exploration learning, we first established a clear context for employing the said elements. Observations and user requirement gathering of a few student groups (classrooms) were conducted to identify student requirements and preferences. In addition, the students were given a questionnaire to gain opinions and feedback on the low fidelity of the proposed Mission to the Star. Based on the findings from the observation and user requirements gathering visit, the proposed Mission to the Star has been developed.

2.2 Development of Game Character

This study uses game character in the design of the Mission to the Star. The role of the Parker Solar Probe agent in the game (see Figure 1) is to provide players with valuable insights about the Sun, as well as fascinating facts and stories related to its behaviour and characteristics. By sharing informative and engaging content, the agent aims to make the game both entertaining and educational for the players.

Fig. 1. The Parker Solar Probe Agent

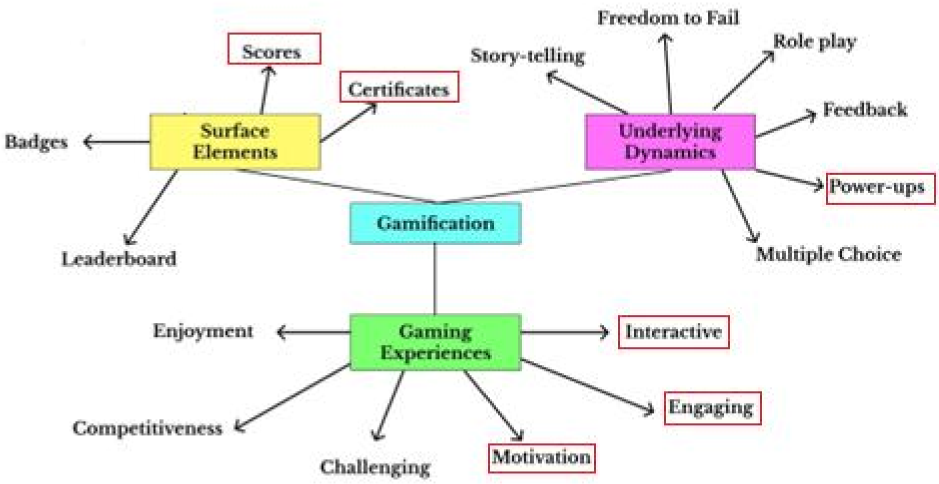
Next character is Kalan (see Figure 2), the stranded space alien, who requires the player's assistance in finding way back to his home planet. The player will help Kalan overcome the obstacles on his journey and ensure his safe return to his home planet, Venus.

Fig. 2. Kalan, the Stranded Space Alien

2.3 Gamification Framework

In order to improve the understanding of how gamification can be used to engage and motivate students in learning activities, this study adapted three types of game elements [26]: surface elements, underlying dynamics, and gaming experience, as depicted in Figure 3. Surface elements refer to game characteristics that are visual and tangible. Among the gamification elements, points, badges, and leaderboards are identified to be most relevant in educational contexts [27]. In addition, we introduce certificates as a reward for completing the game activity, while the scoreboard indicates the summary of the player’s progress in the game journey. Furthermore, underlying dynamics encapsulate a game's underlying dynamic or conditions, such as story-telling, role play, feedback, and multiple choice. Additionally, this study proposes power-ups that let users collect petrol tanks to fill up their fuel bars.

The gaming experience constitutes the third category of game elements. The gaming experience refers to the game-like experience created in a gamified activity, such as enjoyment, challenging, and competition. The game in this study also incorporates motivation, interactive, and engaging to enhance the gaming experience. These game elements synergize to encourage students to remain active in learning and make learning enjoyable.



** The red colour boxes are the new proposed game elements
Fig. 3. The Improved Gamification Framework (adapted from Langendahl *et al.*, [26])

2.4 Establishment of Space Exploration Learning Experience

In Mission to the Star, a single-player concept is applied, and the player will be assigned the responsibility of being a Parker Solar Probe. At the start, the player will be informed of its final destination, which is to reach the Sun's atmosphere. Then, the player embarks on a space exploration journey-based storytelling approach to gain vital knowledge about the Sun and Parker Solar Probe, as in Figure 4 and Figure 5. Next, the player is given the opportunity to test space knowledge in Trivia session (see Figure 6 and Figure 7). The platform offers an exciting leaderboard feature that allows players to compare rankings and overall scores with other participants, fostering a sense of competition and achievement (see Figure 8). Subsequently, the player receives score points, certificates, and badges, which proudly showcase the accomplishments and progress throughout the learning journey. On the other hand, the player is given permission to fail, without penalty; instead, feedback on the correct answers is provided. Along the journey, the player can collect gas to refill the fuel bar (see Figure 9). The workflow of the space exploration learning experience is shown in Figure 10.

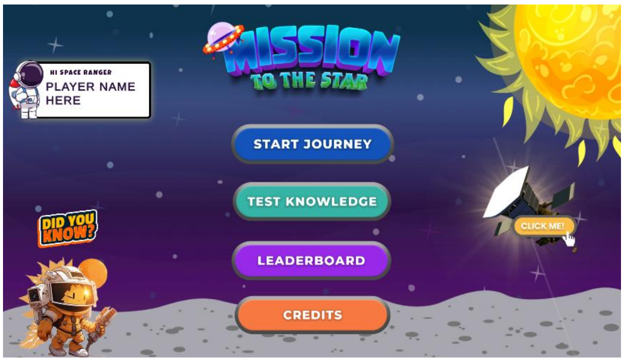


Fig. 4. Mission To The Star

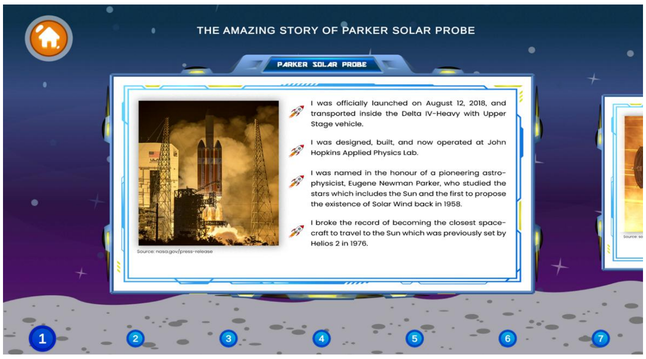


Fig. 5. The Storytelling of Parker Solar Probe

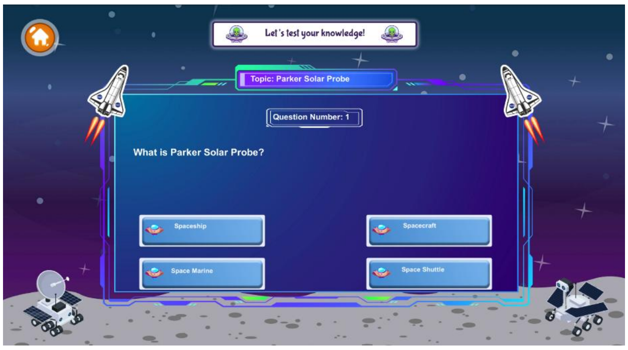


Fig. 6. Trivia Questions

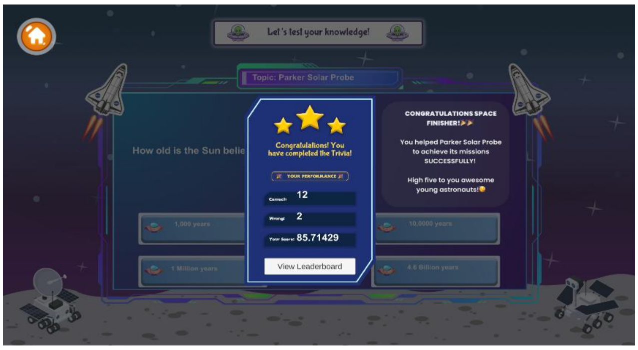


Fig. 7. Score Summary after Completing Trivia

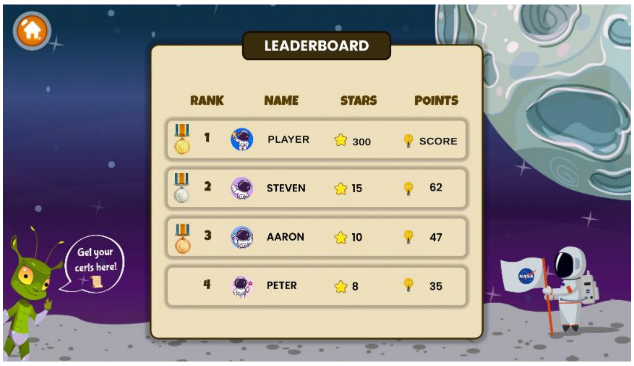


Fig. 8. Leaderboard of Mission to the Star

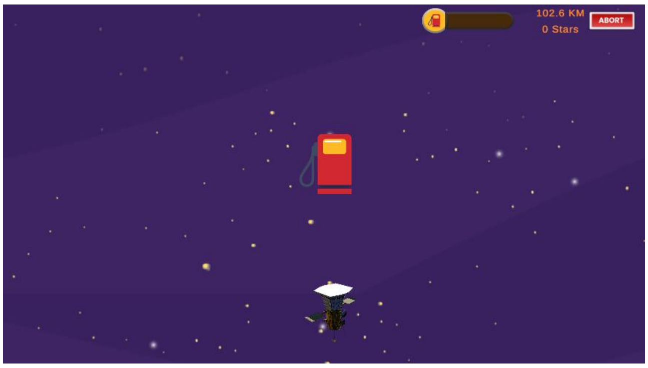


Fig. 9. Parker Solar Probe Collects Gas to Refill Fuel

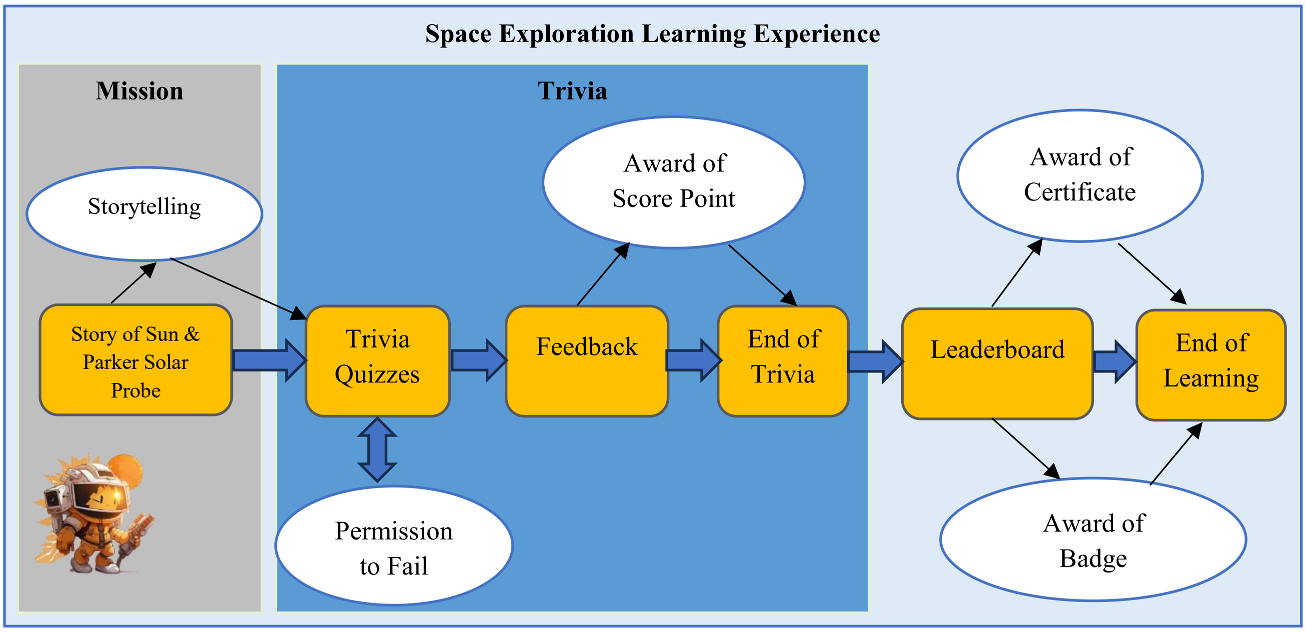


Fig. 10. Workflow of the Space Exploration Learning Experience

Note: The white oval shapes represent the integration of gamification elements, and the yellow square shapes indicate the trajectory of the space exploration learning experience.

3. Results and Discussion

The targeted group of this platform are primary school students in Malaysia. A set of evaluation questions has been prepared for the students after assessing the Mission of the Star platform. This evaluation uses a five-point Likert scale to allows the responders to express how much they agree or disagree with a particular statement or question.

3.1 Playtester Experience

Each level was conducted physically at a primary school located in Malaysia, involving 30 students: 10 students from Primary 4, Primary 5, and Primary 6. Firstly, the team introduced the purpose of the study and provided an overview of the gamified learning platform. Secondly, both Pre-Test and Post-Test questionnaires, consisting of 10 questions divided into two sections (Parker Solar Probe and the Sun), were distributed (see Appendix 1). After the Pre-Test, the students were briefed about Parker Solar Probe and its mission. Subsequently, the Mission to the Star gamified learning platform was introduced, leading to a playtesting session where the students interacted with the platform to learn more about Parker Solar Probe and the Sun. After this interactive session, the students received the Post-Test questionnaires identical to the pre-Test. Finally, the study concluded with a reflection session to assess the students' understanding and insights. The results from both tests are further analysed after completing the playtesting session in the school computer laboratory.

During the session, the students were amazed by the design of the Mission to the Star. They were happy that the platform was ready to be used after the previous user gathering requirement visit. From the observation, the students were motivated to participate in the playtesting session. They were able to understand the Parker Solar Probe’s mission to the Sun. All the students were eager to explore all the features available on the platform. They actively participate and enjoy the learning experience (see Figure 11 and Figure 12). In line with ethical considerations, consent was obtained from the participating students for the use of their photos in this study. The school authorities were informed and approved this usage for educational purposes. All photos have been anonymized, and no identifying information is disclosed to protect the participants' privacy.

Fig. 11. Students Motivate to Participate in the Playtesting Session

Fig. 12. Students Enjoy the Learning Experience

3.2 Student Feedback

Figure 13 shows the positive student feedback that strongly supports the use of the gamification elements in space exploration learning. The Mission to the Star platform successfully engaged and captivated users, resulting in a pleasant and satisfying learning experience. This feedback highlights the platform's effectiveness in fostering an interactive learning environment, thereby encouraging student motivation and participation.

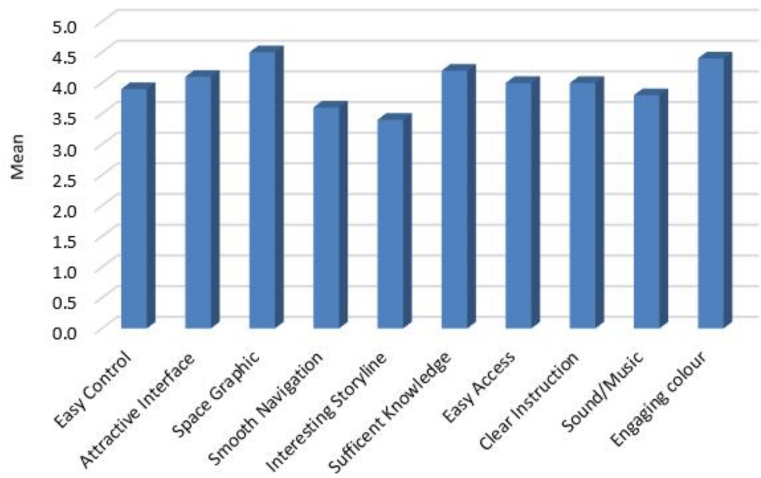


Fig. 13. Students' Feedback on Mission to the Star platform (n=30)

3.3 Gamification Experience

This learning platform proposes numerous game elements, including score board, power-ups, motivation, engaging, interactive, and certification features. These gamification elements are integrated into the platform to enhance motivation and learning, providing users a more enjoyable and rewarding experience. To further assess the impact of gamification on the platform, Pre-Test and Post-Test evaluations were conducted (see Appendix 1), focusing on the content covered in the

Mission to the Star. By comparing the scores before and after using the platform, the impact of gamification in enhancing knowledge retention could be determined.

As shown in Figure 14, the implementation of the Mission to the Star platform has resulted in a significant increase of approximately 5.33% in students' knowledge about the Parker Solar Probe.

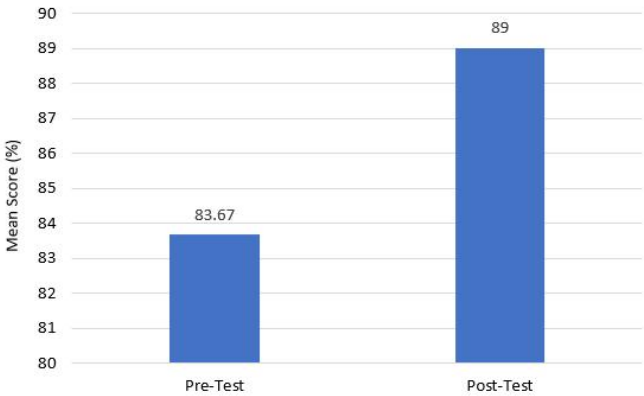


Fig. 14. Mean Score of Pre-Test and Post-Test

Furthermore, the majority of the participants exhibited enhanced scores in the Post-Test in contrast to the Pre-Test, as presented in Figure 15. These findings demonstrate the positive impact and effectiveness of the platform in enhancing the student's understanding of the subject matter. Importantly, this observation indicates a positive shift in the students' performance about space knowledge. In the absence of gamification elements, the space subject might fail to capture interest and sustain retention. However, by integrating gamification elements, the students are motivated to continuously acquire knowledge about the Parker Solar Probe and the Sun.

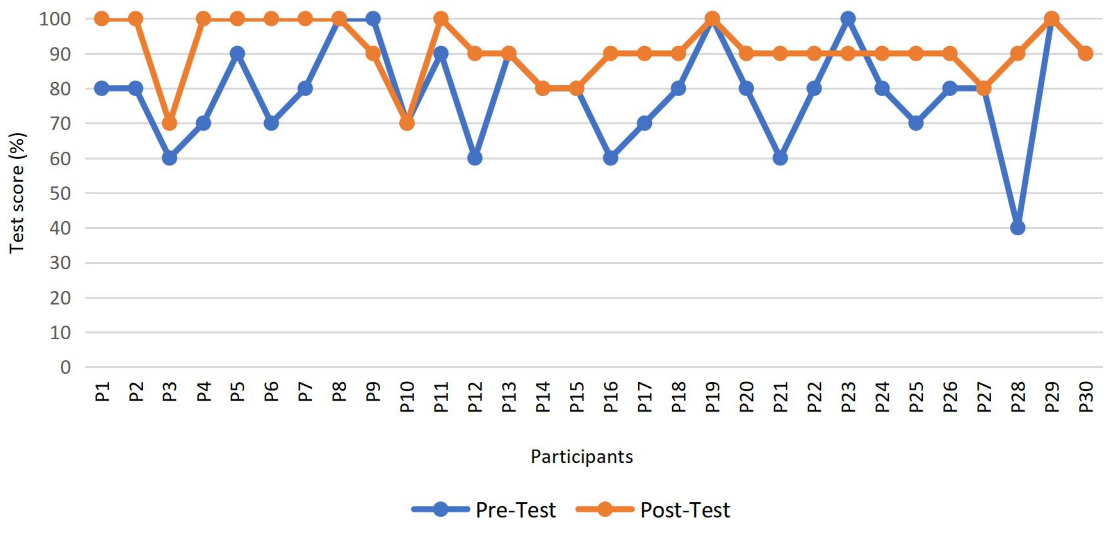


Fig. 15. Pre-Test and Post-Test Scores (n=30)

Furthermore, the Wilcoxon signed-rank test was employed to evaluate the statistical significance of differences between the Pre-Test and Post-Test scores in the context of gamified space exploration learning. The Wilcoxon signed-rank test, a non-parametric statistical method [28], assumes there is no difference between the Pre-Test and Post-Test scores in the null hypothesis (H_o). In contrast, the alternative hypothesis (H_1) assumes that a difference exists between these two measures within the context of gamified space exploration learning. The results of the Wilcoxon signed-rank test revealed the rejection of the null hypothesis (H_o) at the 0.05 significance level (p-value = 0.00028), demonstrating a statistically significant difference between the Pre-Test and Post-Test scores. This statistical significance underscores the impact of gamification on space exploration learning. Therefore, the gamification elements serve as a source of motivation, encouraging students to persistently engage with the platform and explore the vast array of information available.

4. Conclusions

Gamification in education is a modern pedagogical practice to increase student learning performance. The incorporation of gamification elements into the platform has enhanced the students' space exploration learning experience by allowing them to have fun while learning about the spacecraft and the Sun. The platform provides students with vast information to explore and interact with. The students can evaluate their knowledge in the platform's learning environment by completing trivia and reviewing relevant facts about the Parker Solar Probe. In addition, the incorporation of game elements has significantly enhanced the overall experience by allowing students to compare their scores with the scores of their peers and fostering a spirit of healthy competition. In conclusion, gamification should be incorporated into learning as a supplementary tool for enriching space science education and promoting interactive-enjoyable learning experience.

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