

Serious games as pedagogical tools: impact on medical learning at the faculty of Fez

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ABSTRACT

Improving transfusion safety is a major challenge in medicine, requiring rigorous, diversified training for all those involved in the transfusion chain. Objective: This study aims to evaluate the impact of using simulation-based serious games, in particular a fun card game, on medical students' learning of ABO and RHD compatibility principles, with a focus on their ability to retain and apply this crucial knowledge. A total of 260 health students, who had previously attended a lecture course on transfusion compatibility, took part in this study. An educational card game was introduced to reinforce the concepts covered. Students' performance was measured using pre- and post-tests, guaranteeing participants' anonymity. In addition, a satisfaction questionnaire was distributed to assess student acceptance of this fun learning method. Among the 260 participants, the results showed a significant improvement in knowledge, with the mean score rising from 8.12 ± 3.9 before the intervention to 15.89 after the game ($p=0.0001$). The majority of students found the approach simple, engaging and enjoyable, which boosted their motivation and involvement. This study demonstrates that the integration of low-cost, interactive simulation-based serious games can not only boost learners' motivation but also significantly improve their mastery of blood transfusion concepts, making learning more structured and memorable.

Keywords: ABO, Blood transfusion, Compatibility, Medical students, RHD, Serious game

Introduction

The rapid evolution of digital technologies has considerably influenced the landscape of education and vocational training over the last few decades. Among the most striking innovations is the use of simulation as a pedagogical tool. Simulation, defined

as the reproduction of a realistic environment or scenario, has become a mainstay in training in many fields, particularly those where practical skills and decision-making are crucial. Historically, mechanical simulators and manuals were the main means of training in fields such as aviation and engineering. However, with the advent of advanced computer technologies, digital simulations have come to the fore, offering immersive, interactive virtual environments that enable learners to train in near-real-life conditions [1].

Developments in technology now offer trainers the opportunity to diversify the teaching methods they use for educational purposes [2]. Serious games are one example of a new generation of teaching innovation tools that have recently emerged as a means of learning through simulation [3].

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Defined as a hypothetical situation in which players, pitted against each other, are controlled by rules that structure their actions with the aim of achieving learning objectives and goals pre-established by the game, we find that serious games can improve the acquisition of knowledge and skills by learners and increase their motivation [3].

Research into game-based teaching goes back several decades, and since the 1960s many researchers and educators have been interested in integrating games into the teaching-learning process. They have found that games enable students to take an active part in learning, to explore experiment and develop skills in an entertaining way. They also encourage cooperation, creativity and independence [4].

Today, thanks to the positive contribution of play-based methods, many schools are incorporating elements of play into their teaching programs to provide an engaging and enriching learning experience.

At a more advanced stage, a study has shown that the use of serious games in universities has beneficial results in terms of student motivation, active participation in class and improved learning outcomes. Students are more motivated to learn and retain knowledge better when they are exposed to serious games. Similarly, another study shows that integrating serious games into learning programs can help students improve their skills in specific areas. Serious games offer an immersive, hands-on experience, enabling students to apply theoretical knowledge in a real-life context [3, 5].

This pedagogical approach encourages active learning and promotes the development of practical and transferable skills. [6]. Furthermore, in the field of healthcare, the importance of game-based pedagogy for teaching students remains a highly innovative and useful teaching tool. Most card games are multi-player games.

These games are generally used for recreational and leisure purposes. When these games are used for a utilitarian purpose, they are called serious games [7].

Serious gaming represents a strategic convergence of several educational and gaming disciplines, creating an innovative hybrid teaching method. At the heart of this concept is the idea that learning can be not only effective but also engaging by combining essential elements from e-learning, gaming techniques, and immersive narratives specific to video games.

This approach responds to a growing need in the field of education: to make learning more dynamic and interactive, while pursuing serious pedagogical objectives [8].

Serious games capitalize on the power of gamification, which uses the reward and progression mechanisms of games to stimulate learner engagement and motivation. Unlike traditional methods, often perceived as passive or linear, serious games offer a richer educational experience in which the learner becomes a central player in the learning process. By integrating solid educational content and proven gaming techniques, these tools enable learners to explore complex concepts in a controlled, interactive environment while fostering autonomy and critical thinking [8]. In short, serious games represent a holistic pedagogical approach that combines the seriousness of learning with the appeal and

effectiveness of games. They offer educators a flexible and adaptable method for meeting the diverse needs of students, while harnessing the advantages of digital technology to create engaging, interactive and deeply immersive learning environments. This synergy between education and gamification promises to transform pedagogical practices in the long term, with a focus on learner-centered learning, where fun and efficiency go hand in hand [9, 10].

That's why we've opted for a fully-fledged game that combines original card games to help people learn about the transfusion compatibility of blood and blood derivatives. The rules of transfusion compatibility lie in its ability to make learning more engaging and interactive [11]. Students are encouraged to participate actively, which promotes their understanding of key concepts related to blood transfusion [12, 13]. Through games, simulations and hands-on activities, the fun pedagogy allows students to explore various scenarios and make informed decisions about different ABO and RHD compatibility situations. Taking a skills-based approach, we have chosen to integrate innovative teaching tools designed to put learners in problem-solving situations and aimed at training health students, particularly medical and nursing students [14].

Materials and Methods

Article maps

The primary objective of this study is to measure the impact of integrating a specially designed serious card game into the curriculum to improve the knowledge and skills of healthcare students, with a particular focus on medical science students at the Faculty of Medicine, Pharmacy and Dentistry in Fez. This card game, innovative in its conception and application, was designed to teach and reinforce the rules of ABO and RHD compatibility, fundamental concepts in the field of blood transfusion. The interest of this study lies not only in the educational content of the game but also in its accessible and economical format, which sets it apart from more traditional and often costly teaching methods.

The study also aims to assess the effectiveness of this teaching tool in terms of improving students' understanding and ability to retain and apply information about blood groups and their compatibility. By directly involving future doctors in this learning process, we hope not only to enhance their technical skills but also to generate greater interest and awareness of the importance of blood compatibility rules, which play a vital role in patient safety within healthcare establishments.

Description of the study

This is a rigorously planned and executed interventional study, carried out over a three-month period, from April to June 2023, at the Faculty of Medicine, Pharmacy and Dentistry in Fez. The study involved a carefully selected group of medical science students who gave their informed consent to participate in the project. Inclusion of participants was voluntary, with particular

attention paid to informing students in advance of the objectives, methods and potential benefits of their participation in the study. Initially, the students were subjected to a face-to-face lecture course, which covered blood types and the basic rules of blood transfusion in detail. This course was aligned with the faculty's official curriculum, ensuring consistency with current educational standards.

The aim of this first phase was to provide students with a solid theoretical foundation, essential for understanding the critical concepts linked to blood compatibility and the precautions to be taken during transfusions. This theoretical framework served as a reference for assessing the impact of the serious game on learning.

The second phase of the study involved putting theoretical knowledge into practice through serious gaming sessions, specifically designed to reinforce learning about blood compatibility rules. Students took it in turns to participate in these interactive sessions, using an educational card game focused on the ABO and RHD blood group systems. Each serious game session was structured to engage students and encourage active learning while providing a practical review of the concepts covered in the initial course.

Description of the serious game

Thirty-two decks of cards were used in this study, representing the different types and phenotypes of ABO and RHD groupings, namely AB-, AB+, O-, O+, A-, A+, B-, B+. Each contains eight types of cards in quadruplicate [15] (**Figure1**). This research took place at the Faculty of Medicine and Pharmacy of Fez between April and June 2023. The aim of this game is to facilitate the acquisition and learning of the rules of ABO transfusion compatibility RHD for both RGC and FFP transfusion.

The sessions took place in a large room where learners and teachers met. The students were divided into subgroups of four. Thus, each session included approximately 40 students. The teacher began by explaining the principles and rules of the game to the different participants.

Note that the participants could interact with each other during the game and have reflections and peer learning, while the teacher could intervene to explain certain concepts that they did not understand, or were unclear. At the end of the session, the teacher met the participating students for a debriefing session in order to discuss the game, the experiences acquired by the learners, and the learning benefits brought by the game, without forgetting the feelings of the students during serious gaming.

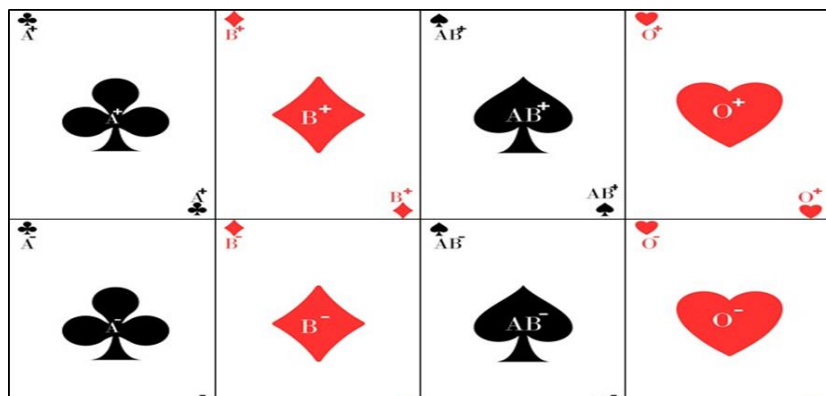


Figure 1. Design of ABO and RHD blood compatibility card sets

Assessment of learning

The assessment of learning in this study was rigorously structured in two distinct stages, measuring knowledge acquisition before and after educational intervention with the serious card game. These stages included a pre-test administered before exposure to the card game and a post-test conducted after the traditional lecture as well as at the end of the game session. The aim was to assess not only the immediate impact of the serious game on students' knowledge but also to compare the effectiveness of the game with. To ensure the anonymity and integrity of the results, each student was randomly assigned a unique number or a fictitious name. This method made it possible to dissociate individual results from participants' identities, thus reducing biases linked to social pressure or recognition.

The tests were designed as multiple-choice questionnaires (MCQs), a format commonly used in academic assessments due to its ability to test a range of skills, from simple memorization to the application of concepts. conventional theoretical teaching.

Specifically, the 16 multiple-choice questions (MCQs) on the pre-test included the ABO and RHD blood transfusion regulations and the derivatives related to these blood type systems. The test's objective was to set a baseline for evaluating students' knowledge before any instructional intervention. A maximum score of 16 points may be earned, with each multiple-choice question worth one point. One point is awarded for a right response; no points are awarded for a wrong response or no response at all. This initial phase lasted fifteen minutes, which was thought to be enough time to evaluate foundational knowledge without overburdening the pupils.

After participating in the traditional lecture on blood groups and transfusion rules, the students then took part in the post-test, immediately followed by a serious game session using the ABO and RHD card game. The post-test was designed to assess the cumulative impact of the theoretical teaching and the game experience on knowledge acquisition. The same multiple-choice questions were used in the post-test, allowing direct comparison with the pre-test results. This provided a clear measure of the

improvement in students' knowledge while isolating the specific effect of card playing compared with traditional teaching.

In addition to the knowledge assessment, a satisfaction questionnaire was distributed at the end of the study to gather students' impressions of the use of the serious game as a pedagogical tool. The questionnaire included several items designed to explore different dimensions of the game experience. Students were asked to indicate whether they had played a serious game before, thus contextualizing their responses in terms of their familiarity with this type of learning method.

The questionnaire also assessed the game's simplicity and fluidity, asking students to rate their experience on a qualitative scale. In addition, an assessment of game enjoyment, i.e., the pleasure felt while using the game, was included to understand whether the ludic aspect of the serious game contributed to student engagement.

So that to measure the perceived difficulty of the game, students were asked to rate it on a scale of 1 to 10, where 1 represented an easy experience and 10 a difficult one. This assessment helped determine whether the game was appropriate for the students' skill level and whether the difficulty was well adjusted to maximize learning without causing frustration.

Finally, the questionnaire asked for an overall rating of the serious game as an instructional tool on a scale of 1 to 10. Students expressed interest in this learning technique, which gave useful information on the game's perceived acceptability and utility in an educational context. To complete this evaluation, students were asked to describe their desire to incorporate comparable serious games within their faculty curriculum. This inquiry was designed to investigate the possibility of generalizing this teaching technique outside the limits of the research.

Data analysis

The data, taken from the MCQs, were entered and analyzed using SPSS version 25.0 software. Qualitative variables were expressed as frequencies (percentages). Quantitative variables were expressed as mean \pm standard deviation after checking the normality of the distribution. In the opposite case (non-Gaussian distribution), the values were reported as the median with the interquartile range (25 and 75%) or the extreme values (minimum and maximum).

Statistical analysis was carried out for quantitative variables using a non-parametric test (Wilcoxon test) for 2 linked samples. The significance level was set at 0.05.

Results and Discussion

A total of two hundred sixty students took part in the game and completed the questionnaires. One hundred and fifty were female and one hundred ten males (sex ratio (M/F) = 0.731).

Pre- and post-test results

Before starting the card game (pre-test), the average number of correct answers was 8.04 (out of a total of 16 points for 16 questions asked) with extremes of 2.5 and 16 (standard deviation 3.784). Ninety-four students (36%) scored above average and only 2 scored 16/16. After the card game (post-test), the median number of correct answers was 15.1, with extremes of 7 and 16. The mean number of correct answers was 13.7 with a standard deviation of 2.734. Ninety-three-nine students (92%) scored above average (8/16) and 88 students (34%) scored 16/16.

Table 1. Pre- and post-test of participants results

Categories	Pre-test	Post-test
Average of correct answers	8.04	13.7
Standard deviation	3.784	2.734
Median score	N/A	15.1
Highest score	16	16
Lowest score	2.5	7
Number of students with score > average	94	99
Percentage of students with score > average	36 %	92 %
Number of students with a score of 16/16	2	88

Comparison of pre-test and post-test responses

The rate of correct answers improved significantly in the post-test compared with the pre-test for 260 students, testifying to the effectiveness of the card game as a learning tool. This improvement reflects a better assimilation of transfusion knowledge after the educational intervention.

More specifically, these results suggest that the students were able to integrate and apply the concepts learned during the game activity, reinforcing the idea that game-based learning can be a powerful means of reinforcing understanding of complex

subjects. It's also interesting to note that, for ten students, the score remained the same before and after using the game, with contrasting results: one scoring 7 points and the other 16. This stagnation could be explained by various factors, such as individual differences in learning styles, pre-existing levels of knowledge, or even external factors that could have influenced their performance during the activity. For these students, it would be relevant to explore these aspects further in order to understand the reasons for the lack of improvement and possibly adapt the game to better meet their specific needs. To evaluate the impact of the card game on knowledge acquisition, a statistical comparison was made between the rates of correct

answers before and after the intervention, using the Wilcoxon test. This test, chosen for its robustness to non-parametric distributions, revealed a statistically significant difference with a $p=0.0001$ value. This statistically significant result confirms that the observed improvement is not due to chance, but is indeed attributable to the effect of the card game.

So, the result found ($p=0.0001$) is particularly strong, indicating that the effect of the card game on student performance is not only positive but also highly reliable from a statistical point of view. This strong statistical significance reinforces the credibility of the study and suggests that the card game teaching intervention

could be a valuable teaching method to integrate into health training programs to improve students' understanding of transfusion rules.

These results also pave the way for reflections on optimizing this pedagogical method, particularly in terms of personalization for students who showed no improvement. In sum, this study, with its innovative approach and robust results, makes a significant contribution to health sciences pedagogy while offering new perspectives for the continuous improvement of teaching methods (**Figure 2**).

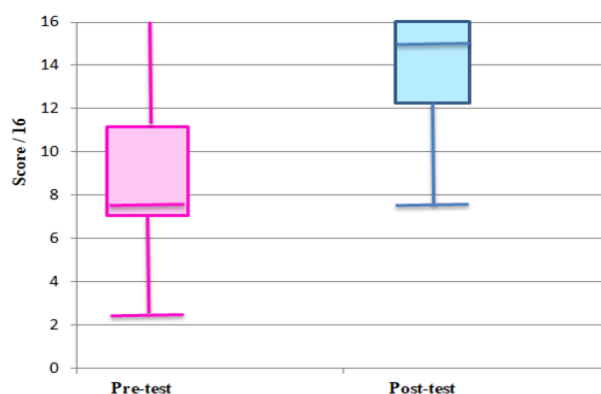


Figure 2. Comparison between pre-test and post-test

Results of satisfaction questionnaire

The majority of the students (250) stated that they had never taken part in a serious game as a means of learning. In addition, they all agreed on the simplicity and fluidity of the game, as well as its enjoyable nature. The students' evaluation of the difficulty of the game, on a scale of 1 to 10 points (1: Easy; 10: Difficult),

showed an average score of 3.24 with a standard deviation of 1.175. For the evaluation of the card game as a teaching tool, the students gave an average score of 9.1/10 with a standard deviation of 0.94. Finally, all the students agreed on the value of using this card game as a means of learning RTS at the faculty, and they expressed their wish for this fun teaching method to be carried out in other courses (**Figure 3**).

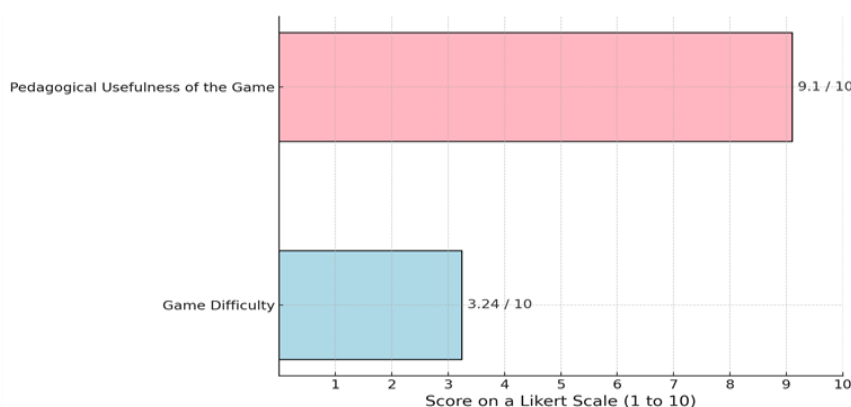


Figure 3. Assessment of student satisfaction

The results of this study show that our low-cost ABO card game increases learner motivation and improves the structuring of knowledge about ABO and RHD RTS for transfusion of RGCs and FFPs. Our original game forms part of the "serious games" that represent one of the means of learning through simulation [16].

"Simulation and games" enable the learner to retain 90% of the content, compared with only 10% when reading games. The improve our decision- making skills. However the boundaries between serious games and simulators are difficult to define as

the nuances are subtle [3, 12]. The objectives of these games can be the transfer and structuring of knowledge, the acquisition of skills, or modifications to the way we learn behavior among learners [17].

However, teachers' interest in the subject is considerable. There are still a number of obstacles to its effective introduction of serious games in training programs. The classic obstacles are logistical and technical problems (premises, preparation time, equipment, etc.). The other obstacle put forward by several

teachers is the difficulty of finding games that are adapted to the teaching program and scientifically validated [18].

The aim of our game is to make it easier to learn ABO and RHD RTS. Our results show that this game, which is inexpensive and easy to generalize improves learner motivation and the structuring of knowledge, and makes learning transfusion rules easier to assimilate in a rather playful atmosphere. These results demonstrate the relevance of games compared with traditional teaching methods alone and explain why they are so popular and acceptability as a means of learning by students. In our study, the results of the pre-test revealed an average rate of correct answers of 8.04 /16 (± 3.77).

The knowledge imparted in the lecture plays a fundamental role in facilitating the transfer of acquired knowledge to new situations, making the serious game more effective in overall learning. Lectures provide a solid theoretical foundation for understanding concepts, which learners can then apply more dynamically and interactively within the serious game. This combination of pedagogical methods promotes deeper understanding as students not only memorize information, but also learn to apply it in a variety of contexts.

Serious gaming then complements this acquisition of knowledge, introducing a playful, immersive approach that further engages learners. Thanks to this approach, students are encouraged to actively use their knowledge, strengthening their ability to solve complex problems independently. Immersion in a game scenario can also facilitate knowledge retention by making learning more memorable and motivating.

Some studies have shown that games that offer the possibility of transferring previously acquired knowledge to new problems are likely to lead to better performance [19]. This transfer of knowledge is essential for the development of transferable skills, i.e., skills that can be applied in a variety of contexts and situations.

Thus, serious gaming is not limited to the simple revision of knowledge, but becomes a powerful tool for applying and deepening that knowledge, which can have a significant impact on students' academic performance. Even in studies where serious games do not surpass traditional learning in terms of knowledge acquisition, it has been shown that they can offer significant benefits in terms of learner motivation and engagement [14, 20].

Serious games are often associated with intrinsic motivation, i.e., motivation that comes from within the individual, which can have positive effects on self-esteem and perseverance in learning. Intrinsic motivation is a crucial factor in educational success, as it motivates learners to invest more in their training.

The use of a serious game in a well-structured and appropriate teaching context can therefore have positive repercussions, as was the case for our students. In our study, we integrated serious gaming as a complement to the lecture, thereby reinforcing the concepts taught while offering a more interactive and dynamic approach to learning [19, 21]. This combination of pedagogical methods aims to maximize teaching effectiveness by capitalizing on the strengths of each approach.

Moreover, this pedagogical strategy, which combines a serious game with traditional teaching, is supported by some authors who consider it more effective than using a game in a purely exploratory way, i.e., for the purpose of discovery without rigorous supervision [13]. Indeed, when games are used in a structured way, they not only engage students, but also guide them towards specific learning objectives, which can lead to better knowledge retention and deeper learning.

This is demonstrated by the average rate of correct answers in the post-test. These results underline the effectiveness of the game and its beneficial contribution as a means of learning. In our study, the learners were participating for the first time in learning through serious games. This active learning method should be encouraged over other passive methods. The latter, centered on the teacher, who communicates knowledge to the learner. The former based on a behavioral approach to the learner [22].

In this card game, the learners were involved in an active learning process and were placed in a problem-solving situation. The diversification of blood transfusion laws in our game, between the transfusion rules for plasma and packed red blood cells, elicits a higher level of reflection and attention from the learners, which engages them more in the learning process. As an educational tool, this game was particularly well received by the students, who emphasized its simplicity, fluidity and the pleasure they experienced while playing it. This positive feedback comes as no surprise, as multiplayer games like our ABO game effectively harness learner motivation through the principle of "learning by doing".

This concept, based on learning by doing, enables students to integrate knowledge in a more active and engaging way. They don't just passively receive information; they actively participate in their own learning by making decisions, solving problems, and interacting with their peers in a playful context [15].

This type of interaction also stimulates in young learners an increased desire to "know more" and to pursue learning beyond mere academic requirements.

The competitive spirit inherent in multi-player games reinforces this motivation, as students not only want to understand the concepts being taught, but also to achieve a certain level of mastery that will enable them to "win". This desire to excel in a competitive setting can lead to better knowledge retention and deeper learning, as students are more likely to revisit concepts learned to improve their performance.

In addition, some modern teaching methods, such as gamification, are increasingly used by teachers to generate a sense of fun and interest in learners [9]. Gamification, which integrates game elements into non-game contexts such as education, transforms sometimes monotonous educational tasks into stimulating activities. This approach encourages students to become more engaged in the learning process, as it introduces challenges, rewards and a sense of progression that make the educational experience more rewarding.

Finally, the accessibility of our game is another of its major assets. Because of its low cost, it is easily accessible to a wide range of audiences, from university students to healthcare professionals and even individuals wishing to train at home. The game can be

used in a variety of environments, whether at university to reinforce theory courses, in hospitals to train future healthcare professionals, or even at home for independent learning [23]. This flexibility of use makes the ABO Game a versatile educational tool, capable of adapting to different learning contexts while offering a teaching method that is both effective and engaging [24].

Conclusion

The present study has successfully demonstrated the effectiveness of the card game in teaching ABO and RhD transfusion rules, highlighting not only its pedagogical advantages, but also its practical feasibility and enthusiastic acceptance by students as an innovative teaching tool. The card game was designed to make learning the complex concepts associated with transfusion compatibility of blood and blood derivatives more accessible and less intimidating for learners, transforming theoretical notions often perceived as dry into an interactive and engaging learning experience.

As a learning method, the card game has proved remarkably effective in simplifying the acquisition and assimilation of knowledge that might otherwise be difficult to grasp. Blood transfusion rules, which are essential to guarantee patient safety during transfusions, require a rigorous understanding of the compatibilities between different blood groups. The game reinforces this understanding through active repetition, where students directly apply the rules in simulated scenarios, promoting longer-lasting retention of the information.

The simplicity of the card game is a major advantage. Unlike more complex or technologically advanced teaching methods, the game requires no expensive or specialized equipment, making it easily accessible and reproducible in a variety of educational contexts. What's more, its low cost makes it particularly attractive for educational establishments with limited resources while offering an effective and innovative pedagogical solution.

The innovative nature of the card game also lies in its ability to capture the interest of students, transforming a potentially boring subject into a fun, interactive activity. This approach not only promotes a better understanding of the subjects covered but also increases motivation among students, who are more inclined to invest in their learning when they find it stimulating and engaging. What's more, using the game as a pedagogical tool helps to diversify teaching methods, offering students different ways of accessing and assimilating knowledge, which can cater to a variety of learning styles.¹⁴In summary, this study underlines not only the pedagogical effectiveness of the card game for teaching ABO and RhD transfusion rules but also its potential as an innovative and adaptable tool, capable of transforming the learning experience into an adventure that is both educational and entertaining.

Nevertheless, although initial feedback from users has been largely positive, it would appear necessary to extend the use of this game to a larger population of students. This would not only

confirm the results obtained so far, but also identify new areas for improvement. In this way, the game could be refined and perfected to better meet the varied expectations of learners and teachers, taking into account the different teaching contexts and skill levels of the students.

Moreover, an interesting prospect to explore would be to measure the effect of the game on students' motivation to get involved in their learning. It would also be relevant to verify whether this serious game can contribute to the development of reflective practice among healthcare students, particularly those in nursing and medical sciences. Indeed, such a tool could encourage students to adopt new and desired behaviors, not only in the field of blood transfusion, but also in other crucial aspects of their training, such as infection risk prevention. This extension of the study would offer research perspectives just as rich as those explored to date, but would inevitably be accompanied by new challenges.

These would include the need to overcome the obstacles associated with generalizing a pedagogical tool to a variety of contexts, as well as adapting the game to maximize its pedagogical effectiveness in different learning environments. Despite these potential difficulties, investment in this direction could prove extremely beneficial, both in terms of improving pedagogical practices and developing the skills of future healthcare professionals.

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Conflict of interest: None

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Ethics statement: All participants were invited to provide their informed consent by signing a consent form prior to their participation in the study. The research strictly adhered to the ethical principles of informed consent, anonymity, and confidentiality. No personally identifiable information was collected, and all data were handled with the utmost discretion. Electronic data were securely stored on a password-protected computer. Furthermore, the study was conducted with the formal approval of the relevant departmental authority.

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