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Serious Game for Learning Gymnastic Elements: Preliminary development and validity assessment

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Abstract

Background: The use of serious games in educational curricula is a new approach to enhance learning outcomes. Specifically, serious games designed for physical education can change the way complex physical skills are taught and learned. Gymnastics, with its detailed elements and techniques, presents a unique challenge for both educators and learners.

Aim: This study aimed to: (i) investigate the potential of serious games in enhancing gymnastic elements teaching and learning in higher education, and (ii) evaluate the effectiveness of two games, G1 and G2, specifically designed for gymnastic elements.

Methods: The study involved 792 university students, with 160 selected based on criteria like active gymnastic course participation, internet access, and gaming history. The participants were divided into four groups based on gaming sequence. After informed consent, they played two serious gymnastic games with five difficulty levels and ten stages targeting fundamental gymnastic elements. The Arabic version of the Game Experience Questionnaire (GEQ) was administered after each gaming session to assess immersion, flow, competence, positive affect, negative affect, tension, and challenge.

Results: The study found significant differences in several variables using the Kruskal-Wallis H test. Flow, Competence, and Positive Affect showed significant differences across groups, with Flow showing the most pronounced difference. Negative Affect and Tension showed no significant differences. Immersion and Challenge were significantly different across groups. Within Group 1, males and females differed in Flow and Competence. A comparison between Male (G1) and Male (G2) showed significant differences in Immersion and Challenge. However, no effect difference was found in Positive Affect. Tension was found to be significant between Male (G2) and Female (G1). Flow and Challenge also varied significantly within Group 2. Females across G1 and G2 showed differences in Competence and Immersion. Overall, the study highlights the importance of understanding and addressing differences in mental health and well-being among different age groups.

Conclusion: The study suggests that serious games can effectively teach complex physical skills like gymnastics within physical education curricula, but further research is needed to understand their long-term educational impacts and optimal implementation strategies in physical education settings.

Keywords: *Educational Technology, Motor Skills, Physical Education and Training, Student Engagement, User Experience, Video Games*

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1. Introduction

Physical education and sports programs often face challenges in engaging students and effectively teaching complex skills, such as gymnastic elements (1). Physical education is taught in many different forms and structures (2), given that curricula are determined at the local level, encompassing national standards, and textbooks (3).Various curriculum models are used in instruction, including movement education, sport education, and fitness education

(4). In terms of engagement in physical activity, two perspectives are apparent (5, 6). When fitness assessment becomes part of a quality physical education program, teaching and learning strategies will guide all students to acquire the knowledge and skills necessary to maintain and improve their personal health-related fitness as part of their commitment to lifelong healthy lifestyles (7). Teachers who incorporate fitness education as a thread throughout all curricula will make the greatest impact in engaging and motivating (8). In Physical education program, gymnastics plays a significant role in promoting the development of students (9). Beyond physical health, gymnastics can cultivate students' psychological and moral qualities as they prepare to enter society. By implementing this practice, college students can enhance their physical fitness and develop valuable psychological and ethical traits simultaneously. (10, 11). However, existing research has highlighted the limitations of traditional teaching methods, particularly in gymnastics, which often rely heavily on verbal instruction and physical demonstration (9). These conventional approaches have been shown to be less effective in promoting the acquisition and retention of complex gymnastic skills, particularly among novice learners. Serious games may offer a unique platform to integrate technology into physical education such as gymnastics and leverage the essential motivation and enjoyment that games offer, providing an interactive, stimulating, and safe learning environment that promotes skill development, social interaction, and physical activity (12, 13).

Actually, the integration of technology has become a pivotal aspect of pedagogy, offering new avenues for engagement, interaction, and skill acquisition (14). Physical education poses a particular challenge due to the difficulty of traditional teaching methods in effectively engaging a diverse student body and imparting complex physical skills (15). Among these, gymnastics stands out as a discipline that combines physical prowess with complex technique, posing significant teaching challenges (16).

Recent advancements in educational technology have led to the emergence of 'serious games' digital games designed for educational purposes beyond mere entertainment (17). These games represent a novel approach in educational settings, providing an immersive and interactive platform for learning (18). In physical education, and specifically in teaching gymnastics, serious games offer an unprecedented opportunity to enhance the learning experience (19). They are capable of creating a captivating and supportive environment that encourages student involvement, facilitates the comprehension of complex movements, and promotes physical fitness in a safe and inclusive manner (20). Serious games have emerged as a promising tool to address these challenges by combining interactive gameplay with educational objectives (21). The burgeoning field of serious games in education has emerged as a pivotal component in contemporary learning environments, offering innovative strategies to enhance educational outcomes across various disciplines (22). This introduction aims to outline the role of serious games in education, drawing upon a wealth of recent scholarly research.

Serious games play a vital role in transforming the setting of physical education by providing innovative and engaging learning experiences (23). These interactive digital games offer a dynamic platform to teach and reinforce physical education concepts, skills, and knowledge in a fun and immersive manner (24). By integrating technology into physical education, serious games capture students' attention, promote active participation, and enhance motivation to learn (25). They provide a safe and inclusive environment for students to practice and refine motor skills, improve coordination, and develop physical fitness (26). Moreover, serious games cultivate problem-solving, critical thinking, and decision-making abilities, promoting both cognitive and physical development (27). The gamified nature of these interventions allows for individualized learning, accommodating different skill levels and promoting student autonomy (28). Overall, serious games in physical education enhance student engagement, facilitate skill acquisition, and contribute to a lifelong enjoyment of physical activity and well-being (29). This article explores the development and evaluation of a serious game designed to enhance the learning experience of gymnastic elements for higher-level physical education and sports students.

2. Methods

2.1. Data collection and procedure

Participants in this study were selected through a careful screening process from a pool of 792 students within the university campus. The inclusion criteria required that participants be students who were actively and permanently engaged in gymnastic courses, had a consistent and permanent internet connection, and had a history of playing internet games. Additionally, participants were required to express a genuine interest in or willingness to engage with the gymnastic serious game under investigation.

After applying these criteria, a sample of 164 students were retained. A set of four male students left the experiment. A final sample of 160 students, (81 females and 79 males), 20.76±1.33, were deemed eligible to participate in the study. To ensure a balanced and randomized design, the remaining participants were randomly assigned to one of four distinct groups based on their gender and the gaming sequence. The randomization procedure was conducted separately for male and female using unique computer-generated random number sequences. The group assignments were kept blinded from the researchers responsible for data collection and analysis to maintain the integrity of the double-blind study design.

The first group consisted of male participants who played Game 1 followed by Game 2, designated as the Male (G1) group. The second group comprised female participants who followed the same sequence, starting with Game 1 and then proceeding to Game 2, designated as the Female (G1) group. The third group included male participants who initiated with Game 2 and subsequently played Game 1, referred to as the Male (G2) group. Finally, the fourth group was composed of female participants who adopted the reverse sequence, commencing with Game 2 and then engaging with Game 1, designated as the Female (G2) group.

All participants voluntarily consented to take part and were informed of the research objectives, data collection procedures, and their rights as research subjects. Confidentiality and anonymity of their responses were assured throughout the study.

2.2. *Ethics*

This study received ethical approval from the Ethics Committee of the High Institute of Sports and Physical Education of Kef, University of Jendouba, Jendouba, Tunisia, with the approval number PHE-07/2023. The present study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and its 2013 revisions, ensuring the research practices adhered to the highest standards in the field of sports medicine and exercise science (30).

2.3. *Game Development*

In this study, two serious games were developed and realized using the WordPress content management system platform. WordPress was selected as the development environment due to its versatility, user-friendly interface, and extensive ecosystem of plugins and themes, which enabled the creation of interactive, web-based gaming experiences. The games were designed to be accessible and playable through standard web browsers, ensuring cross-platform compatibility and ease of access. The interactive game mechanics, user input, and feedback systems were implemented using the various tools and plugins available within the WordPress framework, aimed at engaging the participants and facilitating data collection for the research objectives. Thus, two serious games were developed with a focus on five specific gymnastic elements, targeting both male and female. Each game incorporated five difficulty levels and ten stages to cater to varying skill levels for each sex. The development process involved collaboration between game designers, physical education experts, and instructional technologists to ensure alignment with learning objectives and an engaging user experience (see Figure 1. , https://www.health-games.net/jeux).

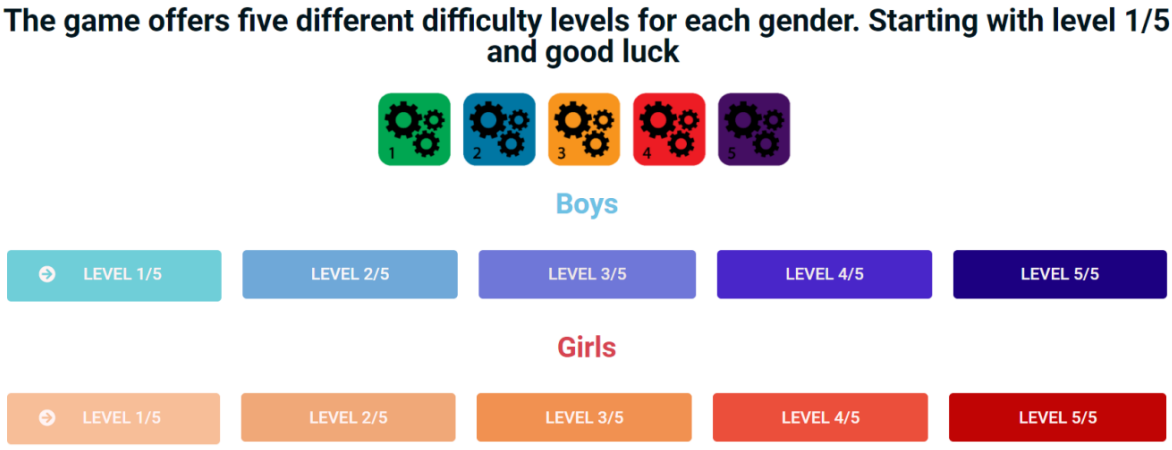

Figure 1. Game Development

The five gymnastic elements, also known as the five fundamental gymnastic movements, form the foundation of gymnastics and are essential for developing strength, flexibility, coordination, and body control. These elements are commonly taught and practiced in gymnastics training programs.

Table 1. Description and benefits

Element	Description	Benefits
Handstands	Body supported entirely on hands in an inverted position. Performed on floor, wall, or apparatus like parallel bars.	Develops core and upper body strength, enhances balance.
Rolls	Smooth body rotations (forward, backward, sideways) while maintaining control.	Improves body awareness, coordination, and teaches safe falling techniques.
Cartwheels	Sideways rotational movement, led by one hand. Performed on the floor or balance beam.	Combines upper body strength, flexibility, and balance.
Bridges	Curved body shape with hands and feet on the ground, back arched upward.	Enhances flexibility in shoulders, back, hips, and strengthens arms and shoulders.
Balances	Static positions requiring control and stability, like tuck balance and scale.	Improves strength, body control, and ability to maintain precise positions.

2.4. Expert Grid

The expert grid includes the following components: (Item 1) Learning Objectives—evaluation of how well the game's goals align with educational outcomes and curriculum standards; (Item 2) Game Mechanics—critical assessment of the game's fundamental rules and interactive elements that drive player engagement; (Item 3) Instructional Design—examination of the pedagogical approaches within the game to ascertain their soundness and ability to facilitate learning; (Item 4) Game Progression—analysis of the game's structure in escalating difficulty and complexity in a way that nurtures the learning process; (Item 5) Skill Development—consideration of the game's effectiveness in enhancing specific cognitive, motor, social, and emotional skills; (Item 6) Assessment Methods—scrutiny of the in-game strategies used to measure the attainment of learning objectives; (Item 7) Feedback Mechanisms—review of the immediacy, quality, and constructiveness of feedback given to players; (Item 8) Overall Experience—evaluation of the total learning experience, including user engagement and satisfaction; (Item 9) Accessibility—assessing the game's design for inclusivity, ensuring it is usable by players with a wide range of abilities and backgrounds; and (Item 10) Adaptability—reviewing how well the game accommodates varying learning styles and can be adjusted for different educational contexts.

2.5. Measurement of Gaming Experience:

The Arabic version of the Game Experience Questionnaire (GEQ) was used to assess criterion validity as it employed to measure various factors associated with the gaming experience (31). The GEQ established reliability and validity, as well as its cultural and linguistic relevance for the Arab student population. The tool assessed immersion, flow, competence, positive affect, negative affect, tension, and challenge. After each gaming session, participants completed the GEQ to provide feedback on their experiences.

2.6. Statistical analysis

The statistical analyses were performed using SPSS version 28 for Windows (IBM Corp, Armonk, NY, USA). The significance level was set at 0.05 to determine statistical significance.

The content validity of the game was assessed using various indexes, including the Content Validity Index (CVI), Item-level Content Validity Index (I-CVI), and Scale-level Content Validity Index (S-CVI)(32). A panel of experts evaluated different aspects and components of the game, including learning objectives, game mechanics, instructional

design, game progression, skill development, assessment methods, feedback mechanisms, and the overall experience. The experts provided ratings or scores for each aspect based on their expert judgment and knowledge. The CVI assesses the proportion of experts who agree on the relevance and representativeness of each aspect. The I-CVI was used to measure the agreement among the experts on the relevance and clarity of individual items within each aspect. While the S-CVI was employed to assess the overall content validity of the game by considering the agreement among the experts on all aspects and their corresponding items. These indexes provide insights into the representativeness, appropriateness, and overall content validity of the game.

Descriptive statistics were reported as means ± standard deviation (SD) for the outcome measures. Prior to conducting inferential testing, the normality of distribution was assessed using the Komologrov-Sminrov test, while the homogeneity of variance was assessed using Levene's test. The Kappa coefficient was employed to assess the reliability of each outcome measure in the Learning Grid. For kappa, the values above 0.74, between 0.60 and 0.74, and the ones between 0.40 and 0.59 are considered as excellent, good, and fair, respectively.

The Mann Whitney test was used fore pairewise comparisons. The magnitude of change was calculated with $r = Z/\sqrt{n}$ formula. Values of 0.5, 0.3 and 0.1 are considered large; medium and small, respectively.

3. Results

3.1. Content validity

The ratings for the second evaluation round presented in Table 2 (appendix2) show significant improvements after necessary changes were implemented. The majority of items, such as Items 1 and 3 through 10, received an I-CVI of 1.0, indicating unanimous agreement among experts that these items were highly relevant, resulting in an "Excellent" validity interpretation. Notably, Item 2's I-CVI improved to 0.9, and Item 7 achieved a perfect score of 1, both now falling into the "Excellent" category. The Scale Content Validity Index/Universal Agreement (S-CVI/UA) reached 0.9, while the Scale Content Validity Index/Average (S-CVI/AVE) attained an impressive 0.99. These results indicate almost perfect agreement according to the expert panel, suggesting that we can proceed with further analysis.

The ratings for the second evaluation round presented in Table 2 (appendix2) show that the majority of items, such as Items 1 and 4 through 10, received an I-CVI of 1.0, indicating unanimous agreement among experts that these items were highly relevant, resulting in an "Excellent" validity interpretation. Item 3, with an I-CVI of 0.90, also demonstrated strong but not unanimous agreement, falling into the "Excellent" category. In contrast, Item 2 and Item 7 had lower I-CVI values of 0.50, suggesting only half of the experts considered them highly relevant, and their content validity was deemed "Poor."

A Kruskal-Wallis H test was employed to examine the differences among the four groups. The results showed significant differences in Flow ($H = 5.07$, $p = 0.024$), Competence ($H = 5.43$, $p = 0.02$), Positive Affect ($H = 9.05$, $p = 0.003$), Immersion ($H = 6.91$, $p = 0.009$), and Challenge ($H = 5.27$, $p = 0.022$), indicating that these psychological states and performance indicators varied significantly across the groups. In contrast, Negative Affect ($H = 0.52$, $p = 0.47$) and Tension ($H = 0.83$, $p = 0.363$) did not exhibit significant differences, suggesting a complex relationship between group dynamics and these specific metrics.

The Mann-Whitney U test was employed to compare game experience between different groups. Comparing Male (G1) to Female (G1), significant differences were observed in Flow ($U = 568.50$, $p = 0.024$, $r = 0.29$, small effect), Competence ($U = 559$, $p = 0.020$, $r = 0.30$, small effect), and Positive Affect ($U = 489.0$, $p = 0.003$, $r = 0.39$, medium effect), indicating gender differences within the same group. Comparing Male (G1) and Male (G2) yielded stronger disparities in Immersion ($U = 227.5$, $p < 0.001$, $r = 0.72$, large effect) and Challenge ($U = 297$, $p < 0.001$, $r = 0.64$, large effect), suggesting the impact of different conditions or interventions between groups. Comparing Male (G1) with Female (G2) showed a moderate effect in Positive Affect ($U = 617$, $p = 0.053$, $r = 0.25$, small effect). Comparing Male (G2) and Female (G1) revealed a substantial effect size in Tension ($U = 343.50$, $p < 0.001$, $r = 0.56$, large effect), indicating significant gender differences within the first group. Gender differences within the second group were observed in Flow ($U = 476$, $p = 0.002$, $r = 0.40$, medium effect) and Challenge ($U = 329.50$, $p < 0.001$, $r = 0.59$, large effect). Comparing Female (G1) with Female (G2), there were smaller yet significant effects in Competence ($U = 598$, $p = 0.04$, $r = 0.27$, small effect) and Immersion ($U = 529.50$, $p = 0.01$, $r = 0.35$, medium effect).

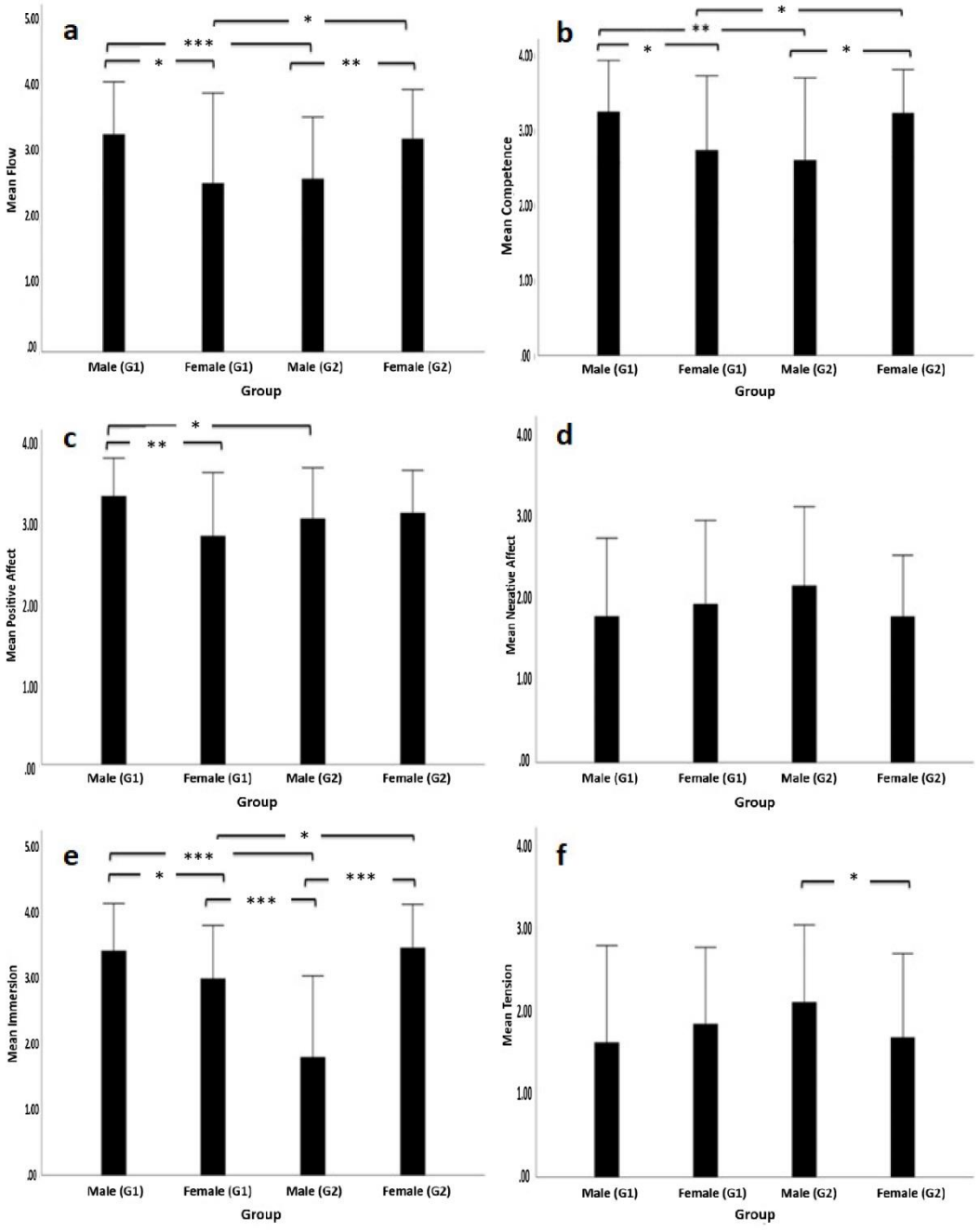

Figure 2. Pairewise comparison

4. Discussion

The main findings of the paper reveal insightful trends in expert evaluations and psychological state measurements across different groups. Expert ratings for specific items demonstrated a high degree of consensus, as indicated by the Item Content Validity Index (I-CVI) and Universal Agreement (UA), with kappa statistics underscoring the significance of these agreements. Furthermore, the Kruskal-Wallis H test results highlighted significant differences among groups in variables like Flow, Competence, Positive Affect, and Immersion, while no notable differences were

observed in Negative Affect and Tension. The Mann-Whitney U test findings were particularly revealing in terms of gender and group dynamics, showing significant variances in psychological states and performance, with notable disparities in areas such as Flow, Competence, and Positive Affect when comparing males and females within and across different groups. These results underscore the complex interplay of gender and group dynamics in educational and psychological outcomes, suggesting that these factors significantly influence the effectiveness of educational interventions and experiences.

In the domain of project management, Jaccard, Bonnier, and Hellström (33) have demonstrated how serious games can catalyze a transformation in educational methodologies, while Daoudi (25) emphasizes the importance of learning analytics in augmenting the usability of serious games in formal education. This suggests a promising future where serious games could become integral tools in various professional fields. Ullah et al. (34) and Gurbuz and Celik (35) have illuminated the significant role of serious games in science and engineering education, highlighting their ability to facilitate complex learning processes in an engaging manner. These studies underscore the potential of serious games to revolutionize traditional educational paradigms, making learning more interactive and impactful.

Focusing on healthcare, Min et al. (36), along with Damaševičius et al. (37), have explored the effectiveness of serious games in nurse and medical education. Their findings reveal that serious games can significantly enhance the learning experience in these areas, offering interactive and practical learning opportunities. Elvsaas et al. (38) and Alonso-Fernández et al. (39) further expand on this by examining the role of serious games in developing critical thinking and awareness among university students, particularly in areas like health claims and bullying prevention. This indicates the broad applicability of serious games beyond just content delivery, extending into the development of essential life skills and attitudes. Moreover, the works of Bakhtiari and Habibzadeh (40) and Bjørner et al. (41) explore into the frameworks and methodologies for designing and evaluating serious games, emphasizing the need for evidence-based approaches in their development. This reflects a growing recognition of the importance of grounding serious game design in solid pedagogical principles to ensure their effectiveness.

The present article showcased the development and evaluation of a serious game specifically designed to enhance the learning experience of gymnastic elements for physical education and sports students at an advanced level.

The analysis of GEQ data revealed positive responses in multiple dimensions of the gaming experience. Participants reported high levels of immersion, indicating a deep engagement with the game. The experience of flow, characterized by a balance between challenge and skill, was reported to be optimal. Competence, positive affect, and challenge were rated positively, indicating a sense of mastery, enjoyment, and engagement with the game. Participants reported low levels of negative affect and tension, suggesting a positive emotional experience during gameplay.

The evaluation of skill acquisition demonstrated a significant improvement in participants' performance in the targeted gymnastic elements after gameplay. The serious game effectively facilitated the learning process, enabling students to acquire and refine their skills in a dynamic and interactive environment.

The findings of this study revealed that the serious game successfully improved the overall gaming experience by positively influencing factors such as immersion, flow, competence, positive affect, and challenge. These results align with previous research that emphasizes the effectiveness of serious games in engaging learners and creating an enjoyable and motivating learning environment.

Importantly, the serious game also demonstrated a positive impact on skill acquisition. The participants showed significant improvements in mastering the gymnastic elements, indicating that the game effectively facilitated the learning process of complex motor skills. This finding highlights the potential of serious games as a valuable tool in physical education, providing students with interactive and practical learning experiences that promote skill development.

The implementation of serious games in physical education carries several advantages (42). By incorporating technology and gamification elements, serious games have the capacity to enhance student engagement, motivation, and overall learning outcomes. The immersive nature of the game creates an environment that captivates students' attention and encourages active participation (43, 44). Additionally, the integration of real-time feedback and challenges within the game allows for immediate assessment and skill refinement.

Furthermore, serious games provide a safe and inclusive platform for students to practice and experiment with various gymnastic elements. This reduces the potential risks

associated with physical activities and promotes a supportive learning environment where students can explore and develop their skills at their own pace. The adaptability of serious games to different skill levels also ensures that all students can participate and progress according to their individual abilities (45).

The positive findings of this study highlight the potential of serious games to revolutionize the field of physical education. Integrating serious games into the curriculum can enhance traditional teaching approaches by offering interactive, engaging, and technologically advanced learning experiences. The capacity of these games is to motivate students, promote skill acquisition, and promote a lifelong interest in physical activity and sports.

However, it is essential to acknowledge that serious games should not replace traditional physical activities but rather complement them. Incorporating a balanced approach that combines both traditional and technological teaching methods can create a comprehensive and effective learning environment.

This study contributes to the growing body of research on serious games in physical education. The results support the effectiveness of serious games in enhancing the gaming experience and facilitating the learning of gymnastic elements. The positive impact on skill acquisition and the potential to improve engagement, motivation, and learning outcomes make serious games a valuable addition to the field of physical education. Future research should continue to explore the optimal design, implementation, and integration of serious games to maximize their educational benefits and promote active and healthy lifestyles among students.

5. Implications and Future Directions

The findings of this study highlight the potential of serious games as an effective educational tool for physical education and sports programs. By providing an immersive and engaging experience, serious games can enhance the learning process and motivate students to develop and refine their skills. Future research should explore the long-term effects of serious game implementation, assess its impact on different populations, and investigate the integration of game-based approaches into formal educational curricula.

6. Conclusion

The study presents a comprehensive evaluation of two serious games, G1 and G2, designed for teaching gymnastic elements in a higher education sports context. The research utilized the GEQ alongside expert content validity assessments to measure the games' educational impact. The findings indicate that both G1 and G2 successfully enhanced the gaming experience, significantly promoting factors such as immersion, flow, competence, positive affect, and challenge among the participants. Moreover, the serious games had a positive impact on skill acquisition, with participants demonstrating considerable improvement in mastering gymnastic elements. These results suggest that G1 and G2 are effective educational tools that can improve engagement, motivation, and learning outcomes in physical education. The study supports the integration of serious games into educational curricula and points towards their potential to revitalize traditional teaching methods by offering engaging, interactive, and technologically advanced learning experiences. Future research should focus on the optimal design and implementation of serious games to maximize their educational benefits and promote active, healthy lifestyles among students.

Acknowledgments

Not applicable.

Ethical Approval and Consent to Participate

This study received ethical approval from the Ethics Committee of the High Institute of Sports and Physical Education of Kef, University of Jendouba, El Kef, Tunisia, with the approval number PHE-07/2023.

Consent for Publication

Not applicable.

Competing Interests

The authors declare that they have no conflict of interest to disclose.

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Authors' Contributions

MR defined the idea and drafted the manuscript. MBA and MMB critically reviewed the manuscript. JH, MS, and

MZ contributed to data collection and analysis. All authors approved the final version of the manuscript.

Declaration

Chat Generative Pre-trained Transformer (ChatGPT) version GPT-4o was used to enhance the academic English and improve the fluency of certain passages in the manuscript (46).

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