Italian Journal of Educational Technology
ISSN 2532-4632 (print) – ISSN 2532-7720 (online)
Accepted Manuscript Online
DOI: 10.17471/2499-4324/1378
https://ijet.itd.cnr.it

Exploring gender dynamics in gamified physics learning – investigating gamification's impact on engagement and learning across genders

Esplorare le dinamiche di genere nell'apprendimento della fisica attraverso il gioco - indagare l'impatto della gamification sull'impegno e l'apprendimento tra i generi

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HOW TO CITE Richter, K., & Kickmeier-Rust, M. (2025). Exploring gender dynamics in gamified physics learning – investigating gamification's impact on engagement and learning across genders. *Italian Journal of Educational Technology*. Accepted Manuscript Online. https://doi.org/10.17471/2499-4324/1378

ABSTRACT This study examines the effects of gamification on student engagement, motivation, and learning outcomes in the Basketball Physics Challenge, a physics-based educational game. Twenty secondary school students (aged 15-18) participated in a crossover study, experiencing both gamified and standard versions of the game. The findings revealed no significant overall gender differences in motivation or performance. However, female learners showed a decrease in motivation after transitioning to the gamified condition, while male learners exhibited a slight increase. Performance metrics indicated males initially scored higher in the gamified condition, while females demonstrated higher engagement, which declined over time. A multivariate ANOVA identified significant gender effects on performance. These results suggest gamification may enhance male learners' performance, while sustaining female engagement may require adaptive strategies. The study highlights the need for gender-specific approaches in gamified educational technologies and suggests further research with larger, more diverse samples to better understand the impact of gamification on learning outcomes.

KEYWORDS Gamification; Motivation; Gender Differences; Learning Outcomes; Physics Education.

SOMMARIO Questo studio esamina gli effetti della gamification sul coinvolgimento, la motivazione e i risultati dell'apprendimento degli studenti nella Basketball Physics Challenge, un gioco educativo basato sulla fisica. Venti

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studenti di scuola secondaria (di età compresa tra i 15 e i 18 anni) hanno partecipato a uno studio incrociato, sperimentando sia la versione gamificata che quella non gamificata del gioco. I risultati non hanno rivelato differenze significative tra i sessi per quanto riguarda la motivazione o le prestazioni. Tuttavia, le studentesse hanno mostrato un calo della motivazione dopo il passaggio alla condizione gamificata, mentre gli studenti maschi hanno mostrato un leggero aumento. Le metriche delle prestazioni hanno indicato che i maschi hanno inizialmente ottenuto punteggi più alti nella condizione gamificata, mentre le femmine hanno dimostrato un maggiore impegno, che è diminuito nel tempo. Un'ANOVA multivariata ha identificato effetti significativi del genere sulle prestazioni. Questi risultati suggeriscono che la gamification può migliorare le prestazioni degli studenti maschi, mentre per sostenere l'impegno delle donne possono essere necessarie strategie di adattamento. Lo studio evidenzia la necessità di approcci specifici per genere nelle tecnologie educative gamificate e suggerisce ulteriori ricerche con campioni più ampi e diversificati per comprendere meglio l'impatto della gamificazione sui risultati dell'apprendimento.

PAROLE CHIAVE Gamification; Motivazione; Differenze di Genere; Risultati di Apprendimento; Educazione alla Fisica.

1. Introduction

Gender dynamics play a significant role in shaping students' experiences in gamified physics learning environments. By examining how gamification influences engagement and learning outcomes across genders, educators can develop tailored approaches that address the diverse needs and preferences of all students. Given the considerable interest in boosting women's motivation and self-efficacy toward STEM subjects such as physics, it is essential to ensure that strategies like gamification are not inadvertently detrimental due to unforeseen gender differences in their effectiveness (Niepel et. al., 2019, Diekman et al., 2010; Boucher et al., 2017). This study reveals the potential of gamification not only to enhance engagement but also to address gender-specific responses, ultimately improving the overall learning experience for all students.

2. Theoretical framework

2.1. Introduction to gamification in education

Game-based learning (GBL) uses games explicitly as the medium for delivering educational content (Plass et al., 2015). Wu (2023) emphasises that Digital Game-Based Learning (DGBL) employs game mechanics to enhance student motivation and learning outcomes, underscoring the role of educators in effectively integrating these tools into classroom practices to align with pedagogical goals. Educational games, frequently employed in GBL contexts, furnish students with opportunities to explore, solve problems, make decisions, and tackle challenges within a structured and interactive framework (Flores, 2016). The impact of these games is twofold: they enhance academic achievement and boost learners' confidence and enthusiasm for learning. These benefits align with the broader educational goals of promoting personal and emotional growth in students (Wei et. al., 2024).

A different, related approach is represented by gamification, the use of game design elements in non-game contexts (Deterding et al., 2011). In the context of education, this involves the integration of specific game mechanics, such as points, badges, leaderboards, and challenges, into the learning process to foster motivation and engagement, without using a full-fledged game. Gamification in education has attracted considerable attention in recent years as a strategy to enhance learning outcomes and student engagement (Deterding et al., 2011). This approach rekindles students' interest in the learning process by making it more appealing and interactive (Malahito & Quimbo, 2020). Research has consistently shown that gamified learning positively influences student motivation, engagement, attitudes, and performance (Hazan et al., 2018). This approach enables students to connect academic tasks to their areas of interest, cultivating a positive disposition toward learning (Karabıyık, 2024). Research indicates that gamification design significantly contributes to academic participation and influences learners' engagement in such environments (Zaric et al., 2021). Gamified learning environments can have a positive impact on cognitive engagement, success, and student motivation (Özhan & Kocadere, 2019). Additionally, the adoption of gamified learning strategies has been linked to potential enhancements in students' willingness to engage in the educational process, learning outcomes, habits, and socialization skills (Kostolányová & Klubal, 2018).

2.2. Gender differences in learning and gamification

Gender differences in learning have been a subject of significant interest in educational research, with studies exploring various aspects such as gender differences in education, gender and motivation in learning, the impact of gamification on male and female learners, and gender differences in educational performance. These investigations shed light on the nuanced ways in which gender influences learning outcomes and educational experiences. This is especially important in the context of the European Union's effort to reduce gender gaps in STEM education and careers (European Parliament, 2021).

The impact of gamification on male and female learners has been explored, revealing differences in how gamified learning environments influence motivation and engagement based on gender (Chung & Chang, 2017). While male learners may exhibit a higher preference and motivation for digital game-based learning, female learners might demonstrate higher cognitive abilities in certain aspects of the learning content (Chung & Chang, 2017). Efforts to reduce gender gaps in STEM teaching must account for the potential unintended consequences of teaching techniques that might be more effective for one gender than the other. Failing to address these disparities could inadvertently reinforce existing inequities (European Parliament, 2021).

Understanding gender-specific responses to gamification can help educators design more inclusive learning experiences that meet the diverse needs of all students, while also promoting gender equity in educational and career outcomes.

2.3. Gamification as a tool to bolster motivation

Gamification is increasingly recognized for its potential to transform traditional learning experiences by making them more interactive, enjoyable, and rewarding (Martí-Parreño et al., 2016). However, its impact on intrinsic and extrinsic motivation depends significantly on the design and implementation of game elements. While gamification can foster intrinsic motivation by creating engaging learning environments, it also leverages extrinsic motivators such as points, badges, and leaderboards to enhance engagement (Deci & Ryan, 1985; Khatoon, 2023).

While extrinsic motivators have the potential to enhance engagement initially, an over-reliance on these elements may result in a shift from meaningful learning to the accumulation of rewards. This phenomenon has been critiqued by Robertson (2010) as "pointsification". To counteract this, Hellberg and Moll (2023) argue that effective gamification should go beyond superficial rewards and incorporate game-thinking principles—such as narrative, interactivity, and problem-solving—to sustain intrinsic motivation.

Additionally, gamification can enhance learner autonomy and competence, key components of Deci and Ryan's (1985) Self-Determination Theory, by making abstract concepts more tangible and fostering experiential learning opportunities.

Gamification design is also relevant for gender differences in gamified activities' reception. Male learners often engage more with competitive elements, while female learners may prefer collaborative or narrative-driven tasks (Chung & Chang, 2017). To ensure inclusivity, gamification strategies should incorporate diverse approaches that cater to different motivational drivers. The thoughtful integration of both intrinsic and extrinsic elements has the potential to engender sustained engagement and equitable learning experiences, whilst simultaneously mitigating potential gender disparities in motivation and performance.

3. Present study

The primary aim of the Basketball Physics Challenge project was to assess how gamification elements influence student engagement, motivation, and learning outcomes in an educational game designed to impart basic physics concepts. With the growing integration of digital educational technologies in classrooms, this game offers an innovative, hands-on approach to understanding theoretical concepts such as initial velocity, motion and trajectory, throwing angle, gravity, friction, and air resistance. Another key objective was to examine how varying sequences of gamified and non-gamified conditions impact learning outcomes and motivation over time.

3.1. Research objectives and hypotheses

Based on the project's main goal of exploring the impact of gamification on engagement, motivation, and learning performance in physics, we aimed to investigate the effects of gamification elements on female and male learners for their performance and motivation in a physics learning app. Given the small sample size, the analyses are framed as exploratory, and the results should be interpreted with caution due to limitations in statistical power. The following hypotheses were formulated and tested:

Hypothesis 1: Gender Differences in Motivation. It is expected that there will be significant differences in self-reported motivation between male and female learners prior to and after using the gamified physics learning app. This hypothesis will be tested by analyzing self-reported motivation scores before and after each session.

Hypothesis 2: Impact of Gamification on Learning Performance. This hypothesis posits that the use of gamification in the physics learning app will result in significant differences in learning performance (measured by time on task and scores) between male and female learners.

Accepted Manuscript Online. DOI: 10.17471/2499-4324/1378

These hypotheses aim to provide deeper insights into the effects of gamification on engagement, motivation, and learning performance in physics-based educational games. While the results are exploratory, the study seeks to highlight the potential of gamification to sustain engagement and improve learning outcomes, focusing on understanding its effects on different learner demographics.

4. Method

4.1. Participants

The study involved 20 students from a secondary school in Liechtenstein, who were in the optional 10th grade, an additional school year following the regular curriculum. Participants ranged in age from 15 to 18 years (M = 16.25, SD = 0.76). The sample consisted of an equal distribution of 10 female and 10 male students. Sixty-five percent of the participants were native German speakers. The overall physics scores of the students were generally on the lower end, indicating that their performance was modest relative to expected proficiency levels for 10th-grade students. While specific national benchmarks were not available, the observed mean scores suggest that participants may have faced challenges in physics, which could influence their engagement and learning outcomes when using the gamified learning app.

4.2. Study design

The study employed a crossover design to examine the effects of gamification on performance and motivation in an educational game. Participants were divided into two groups to compare two game versions: one with gamification elements (the gamified condition) and one without (the standard condition). Each group experienced both versions in different sequences, allowing for individual differences to be controlled while reducing the number of required participants.

Participants were randomly assigned to one of two groups:

- **Group 1:** Played the gamified version in Session 1 (t1) and the standard version in Session 2 (t2).
- **Group 2:** Played the standard version in Session 1 (t1) and the gamified version in Session 2 (t2).

The purpose of this sequence was to investigate the effects of gamification across time while minimizing order effects. Session 1 served as the baseline measurement, and Session 2 allowed us to observe changes in performance and motivation when participants switched conditions.

Physics comprehension was measured through a quiz administered before and after each game version. Additionally, a motivation questionnaire was given before and after each session to assess changes in self-reported motivation.

Differences Between Gamified and Standard Versions. The Basketball Physics Challenge was offered in two versions: a gamified and a standard version, designed to explore gamification's impact on motivation and engagement. The gamified version featured colorful visuals, playful graphics, and an immersive robot avatar, contrasting with the plain design of the standard version. It also included engaging game mechanics, such as a timer to create urgency and a points system to reward task completion.

Storytelling and competitive elements further distinguished the gamified version, embedding physics problems within a narrative to enhance relatability. The standard version, by contrast, presented the same tasks without these features, using a straightforward and traditional format.

These gamified enhancements aimed to boost immersion, motivation, and accomplishment, illustrating gamification's potential to transform educational tools. In comparison, the standard version lacked these interactive and motivational elements, focusing solely on delivering the physics content.

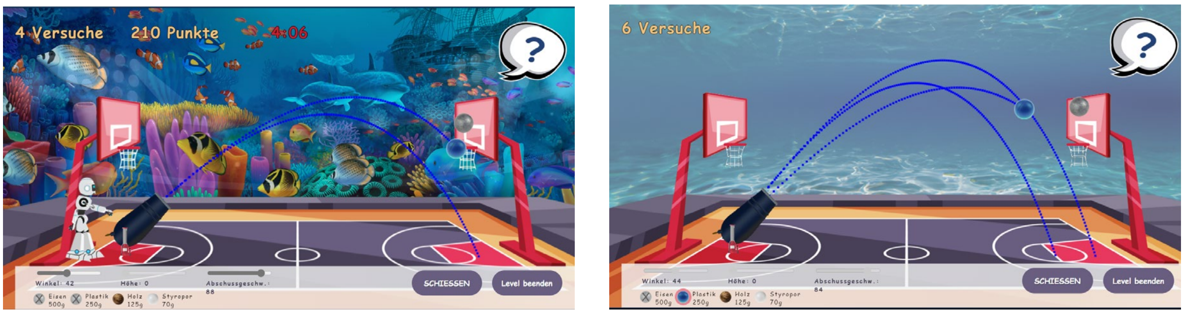


Figure 1. Screenshots of the Basketball Physics Challenge, with the gamified version on the left and the non-gamified version on the right, highlighting the differences between the two modes.

4.3. Learning task and quiz structure

The learning task was designed to teach and apply basic physics concepts in an interactive environment. Participants completed a physics quiz before and after each gamified and standard version session, assessing their understanding of concepts such as initial velocity, motion, trajectory, throwing angle, gravity, friction, and air resistance. The game required players to adjust variables to throw a ball into a basket using a cannon, enabling them to test hypotheses about physical effects and learn through direct feedback.

4.4. Level structure and quiz integration

The game levels progressively introduced physics concepts, following a competency model aligned with international curricula, particularly the Swiss *Lehrplan 21* (NT.5.1.3.b). The thematic focus on forces and motion required students to explore the effects of forces, such as changes in a ball's trajectory. The domain was broken into atomic competencies—small units of knowledge or skills—to ensure a clear progression. Content began with basics like initial velocity and throwing angles, advancing to complex topics such as gravitational effects on different planets and wind resistance. This balance avoided excessive fragmentation while ensuring comprehensive coverage. Competency identification was guided by physics textbooks, *Lehrplan 21*, and research on misconceptions like parabolic motion and force relationships. A hierarchical competency tree visualised dependency, ensuring levels logically built upon each other to strengthen foundational knowledge. To evaluate understanding, participants completed a pre-test and post-tests for both game versions, allowing direct assessment of gamification's impact.

4.5. Motivation Questionnaire

A motivation questionnaire was administered at four key points (T1 pre, T1 post, T2 pre, T2 post) to assess changes across five motivational dimensions: intrinsic motivation, extrinsic motivation, well-being, emotional influence, and emotional factors.

Internal consistency was evaluated using Cronbach's alpha, revealing variability across dimensions and time points. Specifically, MOT1 exhibited low internal consistency at T1 pre ($\alpha = 0.27$) but demonstrated a substantial improvement at T1 post ($\alpha = 0.84$). In contrast, MOT2 displayed moderate internal consistency at T2 pre ($\alpha = 0.63$), with a slight increase at T2 post ($\alpha = 0.69$).Test-retest reliability, assessed through correlations between pre- and post-scores, indicated moderate stability for MOT1 ($r = 0.59$) and MOT2 ($r = 0.61$). These results suggest that MOT1 exhibited greater temporal fluctuations, while MOT2 maintained more stable reliability over time.

The validity of the questionnaire was supported by its theoretical foundation in established motivational constructs (Deci & Ryan, 1985) and the alignment of dimensions with key aspects of motivation. For interpretive consistency, negatively worded items were reverse-coded, ensuring that higher scores consistently reflected greater levels of motivation, satisfaction, or well-being. Responses were recoded and categorized into the five main dimensions, with mean scores calculated to provide aggregated results.

5. Results

The results of the Basketball Physics Challenge study offer comprehensive insights into the impact of gamification on teaching physics concepts and its influence on learning performance and motivation among male and female learners. Initial analyses visualized the group distribution across different measurement time points to illustrate participant engagement and participation. Descriptive statistics, including mean values and standard deviations, were calculated for total scores at each measurement point to assess learning progress and the effectiveness of gamification elements.

5.1. Gender differences in motivation

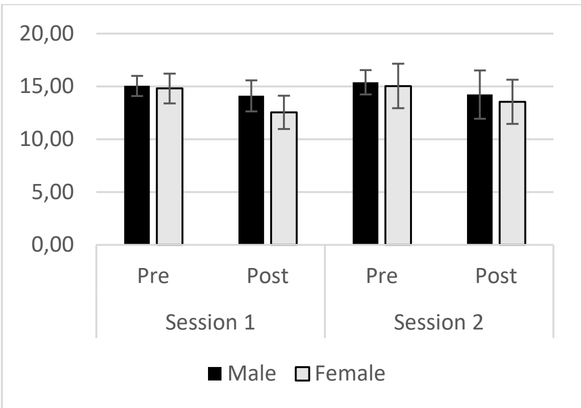


Figure 2. Self-Reported Motivation Scores for Males and Females Before and After Each Session. The chart illustrates the average motivation scores for male and female students before and after Session 1 and Session 2.

For male participants, no significant differences in motivation scores were found between pre- and post-intervention in Session 1 ($M = 15.04$, $SD = 0.94$ vs. $M = 14.11$, $SD = 2.94$), $t(8) = 1.03$, $p = .333$. Similarly, in Session 2, the difference in motivation scores before ($M = 15.38$, $SD = 1.15$) and after ($M = 14.23$, $SD = 2.29$) using the app was not statistically significant, $t(8) = 1.58$, $p = .153$.

For female participants, significant decreases in motivation scores were observed in both sessions. In Session 1, motivation scores significantly declined from $M = 14.80$ ($SD = 1.40$) to $M = 12.54$ ($SD = 3.38$), $t(9) = 2.75$, $p = .023$, suggesting a notable reduction in motivation after using the app. In Session 2, this effect was even more pronounced, with a decline from $M = 15.03$ ($SD = 2.11$) to $M = 13.54$ ($SD = 2.10$), $t(9) = 3.51$, $p = .007$. The larger t-value in Session 2 indicates a stronger effect compared to Session 1, suggesting a cumulative or reinforcing negative impact of the intervention on female participants' motivation.

The findings indicate a differential impact of the learning app on male and female participants. While motivation levels for male participants remained stable across both sessions, female participants experienced a significant decline in motivation after using the learning app. This effect was more pronounced in the second session, potentially indicating that the gamification elements did not sustain engagement for female learners or that their initial expectations were not met over time. These results suggest the need for a more tailored approach in designing gamified learning interventions that better address gender-specific motivational dynamics.

Consistent with these results, we found homogenous results for motivation across gender and condition. The detailed mean values and standard deviations (SDs) for self-reported motivation scores before (pre) and after (post) using the learning app in both sessions are provided below (Table 1).

Table 1. Pre- and Post-Intervention Motivation Scores Across Different Conditions and Time Points. Values represent mean scores and their corresponding standard deviations (SD) for self-reported motivation before (pre) and after (post) the intervention across conditions (G_m: gamified condition, males; G_w: gamified condition, females; S_m: standard condition, males; S_w: standard condition, females) and sessions (t1: session 1, t2: session 2).

	G_m	**G_w**	**S_m**	**S_w**
t1 pre	14.88 (.86)	15.30 (1.16)	15.37 (1.21)	14.31 (1.59)
t2 pre	16.02 (.62)	13.84 (1.62)	15.06 (1.86)	16.21 (1.97)
t1 post	15.25 (1.37)	14.97 (1.37)	11.84 (4.27)	10.10 (3.00)
t2 post	15.29 (2.70)	12.27 (1.87)	13.70 (0.50)	14.81 (1.53)

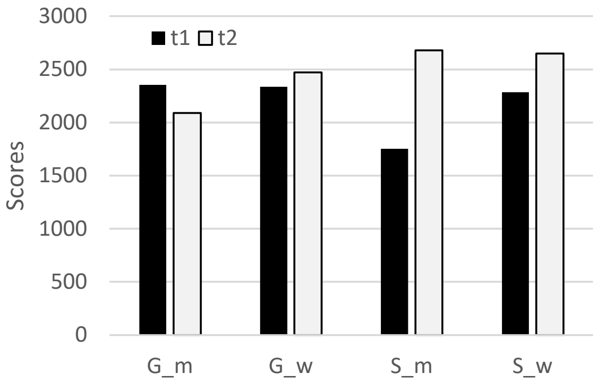
5.2. Gender differences in performance

Similarly, no gender differences were found in performance (time on task, scores) using the learning app in both sessions. A paired-samples t-test was conducted to examine potential differences in performance metrics, including time on task and scores, before and after using the learning app for both male and female participants.

Time on Task: For male participants, there was no significant difference in time on task between Session 1 (M = 609.11, SD = 147.30) and Session 2 (M = 611.56, SD = 148.10); $t(8) = -0.04$, p = .967. For female participants, a marginally significant decrease in time on task was observed between Session 1 (M = 620.30, SD = 228.03) and Session 2 (M = 536.00, SD = 135.74); $t(9) = 2.17$, p = .058.

Scores: For male participants, a significant increase in scores was found between Session 1 (M = 2154.44, SD = 404.11) and Session 2 (M = 2483.33, SD = 580.37); $t(8) = 7.99$, $p < .001$. For female participants, no significant difference in scores was found between Session 1 (M = 2310.00, SD = 296.06) and Session 2 (M = 2561.00, SD = 364.58); $t(9) = -1.51$, p = .167.

These results indicate that both male and female learners performed similarly in terms of time on task and scores, regardless of the gamification elements. While male participants exhibited a significant increase in scores from Session 1 to Session 2, female participants showed no significant improvement



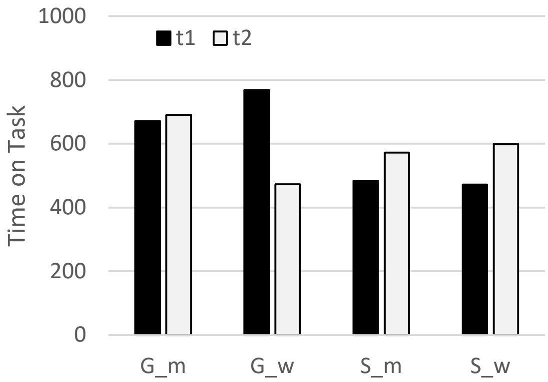
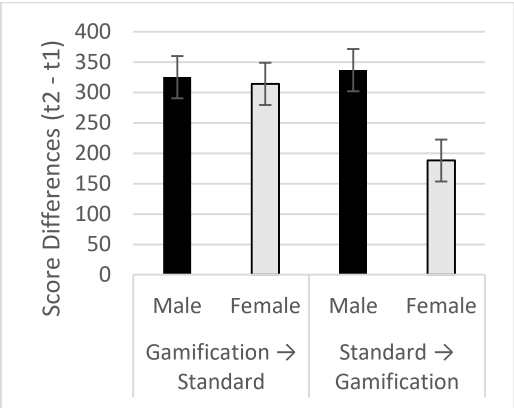


Figure 3. Comparison of Scores and Time on Task Between Sessions: **(a)** Performance scores for males (m) and females (w) in the gamification (G) and standard (S) conditions across sessions t1 and t2; **(b)** Time on task for males and females in both conditions.

5.3. Condition effects on performance

The analyses of condition effects on (gamification vs standard) revealed a distinct difference for males in scores in the standard condition. In session 1 (t1), males tended to achieve lower scores in the standard condition compared to session 2 (t2) (Figure 3a). A repeated measures ANOVA yielded a significant effect for the main factor condition ($F(1, 17) = 5.623$, $p = .030$, $\eta^2 = .06$). In turn, Figure 3b shows that female learners tended to spend more time on task in the gamification condition in session 1 and less time in the gamification condition in session 2, as opposed to the other groups (males and standard condition). The repeated measures ANOVA yielded a significant effect for the interaction Session * Condition ($F(1, 17) = 333.777$, $p < .001$, $\eta^2 = .50$). These findings suggest that gamification elements positively impacted males' scores, while females showed higher engagement in terms of time on task initially, but this engagement decreased over time.

5.4. Additional analyses



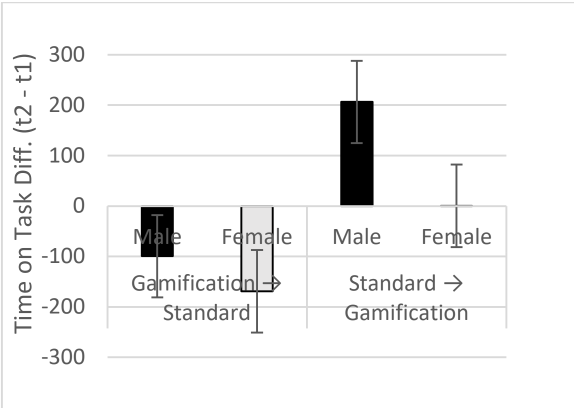


Figure 4. Differences in scores and time on task between sessions t1 and t2 for gamified (G) and standard (S) conditions across genders: **(a)** Score differences for males (m) and females (w); **(b)** Time on task differences for males and females.

Given the within-subject design of the presented study, it is of interest to investigate the individual changes from session 1 to session 2. The results summarized in Figure 4a show that male participants experienced greater improvements in scores compared to females, particularly when starting with the standard condition followed by the gamification condition. While both GS_m and GS_w groups showed score increases, the increase was less pronounced for females in the SG_w group.

Figure 4b illustrates differences in time on task. Male participants in the SG_m group, who started with the gamified version, showed a clear increase in time on task, whereas females in the same sequence (SG_w) showed no changes. Participants in the GS_m and GS_w groups, who began with the standard condition, demonstrated a reduction in time on task during the second session.

A multivariate ANOVA yielded significant effects of gender on the score differences, highlighting that gender plays a crucial role in how learners respond to gamified versus standard conditions. The detailed results of the multivariate ANOVA are as follows:

For the Score Difference (SCORE_DIFF), the corrected model showed no significant overall effect ($F(3, 15) = 0.078$, $p = .971$, $\eta^2 = .01$). However, the constant term was significant ($F(1, 15) = 5.120$, $p = .039$, $\eta^2 = .25$), indicating that there were significant overall differences in scores. Regarding the Time on Task Difference (ToT_DIFF), the corrected model was highly significant ($F(3, 15) = 13.534$, $p < .001$, $\eta^2 = .73$), suggesting substantial differences in time on task across the conditions. The constant term was not significant ($F(1, 15) = 0.585$, $p = .456$, $\eta^2 = .04$), but significant effects were found for the main factor of gender ($F(1, 15) = 11.623$, $p = .004$, $\eta^2 = .44$) and condition ($F(1, 15) = 34.603$, $p < .001$, $\eta^2 = .69$). The interaction between gender and condition approached significance ($F(1, 15) = 2.852$, $p = .112$, $\eta^2 = .16$).

These results underscore the complex dynamics between gender, engagement, and performance in gamified educational settings. Males and females responded differently to the sequences of standard and gamified conditions, with significant implications for the design and implementation of educational technologies aimed at enhancing learning outcomes.

5.5. Subscales of motivation

The analysis of the five subscales of motivation—intrinsic, extrinsic, well-being, emotional, and emotional factors—yielded no distinct differences across gender and condition. Below are the detailed results for each subscale:

Table 2. Pre- and Post-Intervention Scores Across Different Dimensions and Sessions. Values represent mean scores and their corresponding standard deviations (SD) for self-reported motivation before (pre) and after (post) the intervention across conditions (gamification-first, standard-first) and sessions.

		Session 1					**Session 2**				
		intrinsic	*extrinsic*	*wellbeing*	*emotional*	*emot.fact.*	*intrinsic*	*extrinsic*	*wellbeing*	*emotional*	*emot.fact.*
Pre	*G-S m*	3.08 (0.82)	3.11 (0.53)	2.89 (0.54)	3.17 (0.61)	2.63 (0.49	3.00 (0.35)	3.11 (0.34)	2.94 (0.34)	3.33 (0.52)	2.67 (0.34)
	G-S-f	2.95 (1.49)	3.40 (1.42)	2.80 (1.06)	3.30 (1.24)	2.85 (1.42)	3.35 (0.63)	3.18 (0.22)	2.93 (0.55)	3.40 (0.65)	3.35 (0.52)
	S-G-m	3.50 (1.49)	3.26 (1.42)	2.61 (1.06)	2.83 (1.24)	3.17 (1.42)	3.00 (0.00)	3.19 (0.42)	3.33 (0.58)	3.33 (0.58)	3.17 (0.29)
	S-G f	2.85 (1.49)	3.22 (1.42)	2.33 (1.06)	3.10 (1.24)	2.80 (1.42)	2.55 (0.91)	2.62 (0.78)	2.47 (0.57)	3.40 (0.55)	2.80 (0.21)
Post	*G-S m*	3.42 (0.82)	3.04 (0.57)	2.81 (0.49)	2.92 (0.55)	3.07 (0.41)	2.83 (1.17)	2.79 (0.90)	2.56 (0.56)	3.08 (0.58)	2.43 (0.64)
	G-S-f	3.30 (0.29)	2.80 (0.18)	2.93 (0.03)	3.30 (0.13)	2.64 (0.13)	2.80 (0.57)	3.00 (0.32)	2.73 (0.73)	3.40 (0.42)	2.88 (0.59)
	S-G-m	2.17 (0.28)	3.38 (0.05)	2.17 (0.06)	2.33 (0.10)	1.80 (0.03)	3.00 (0.00)	3.04 (0.07)	3.11 (0.19)	3.00 (0.00)	3.13 (0.23)
	S-G f	2.00 (0.60)	2.48 (0.62)	1.77 (0.51)	2.30 (0.54)	1.56 (0.65)	1.80 (0.84)	2.73 (0.19)	2.20 (0.52)	2.90 (0.74)	2.64 (0.46)

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5.6. Effects of gamification sequence on motivation

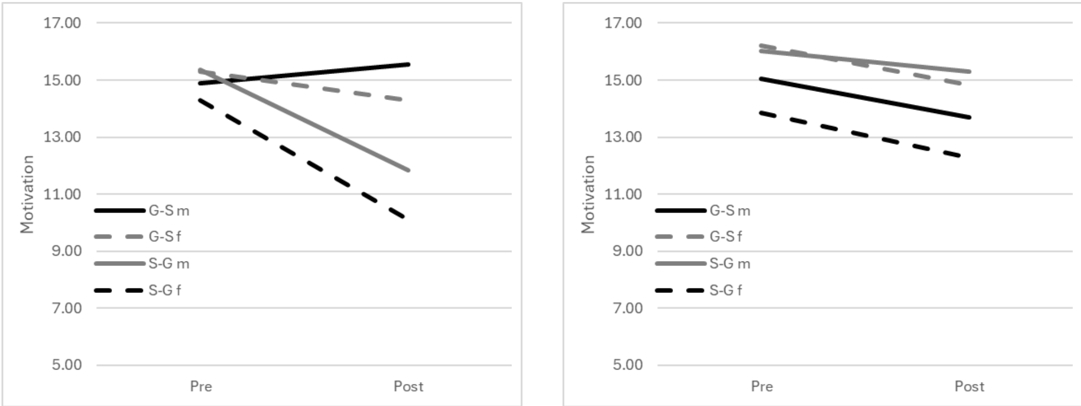

Figure 5. Changes in self-reported motivation before (Pre) and after (Post) the intervention for the gamification-first (G-S) and standard-first (S-G) sequences: **(a)** Motivation changes in Session 1 for males (m, solid lines) and females (f, dashed lines); **(b)** Motivation changes in Session 2 for males and females.

The effects of the gamification sequence on self-reported motivation were analyzed across gender and intervention order, as illustrated in Figure 5. The overall motivation scores were calculated as the average of responses across four subscales: intrinsic motivation, extrinsic motivation, interest in physics, and satisfaction/well-being. Intrinsic motivation reflects enjoyment of and engagement with the task itself, while extrinsic motivation refers to external incentives, such as scores or rewards. Interest in physics captures enthusiasm for the subject matter, and satisfaction/well-being assesses emotional states, such as contentment or stress, during the sessions. As shown in Figure 5a, when investigating the self-reported motivation for the groups gamification first (G-S) and standard first (S-G) by gender in session 1, we found a distinct effect of the intervention order; males yielded an increase in self-reported motivation in the gamification condition (pre 14.88 (SD = 0.86); post 15.25 (SD = 1.37)), while females showed a decrease of motivation the gamification condition (pre 15.3 (SD = 1.16); post 14.97 (1.37)). In the standard condition, both genders yielded a decrease in motivation (males: pre 15.37 (SD = 1.21); post 11.84 (SD = 4.27); females: pre 14.31 (SD = 1.59); post 10.10 (SD = 3.00)). A repeated measures ANOVA yielded a significant main effect of gender ($F(1, 15) = 5.799$, $p = .015$, $\eta^2 = .45$) and condition ($F(1, 15) = 16.430$, $p < .001$, $\eta^2 = .70$). The gender-group interaction was not statistically significant ($F(1, 15) = 1.477$, $p = .262$, $\eta^2 = .17$).

As shown in Figure 5b, when investigating the self-reported motivation for the groups gamification first (G-S) and standard first (S-G) by gender in session 2, we found a general drop in motivation. In condition G-S males reported a motivation of 16.02 (SD = 0.62) in the pretest and 15.29 (SD = 2.70) in the posttest, females a motivation of 13.84 (SD = 1.62) in the pretest and 12.27 (SD = 1.87) in the posttest. In condition S-G males reported a motivation of 15.06 (SD = 1.86) in the pretest and 13.70 (SD = 0.50) in the posttest, females a motivation of 16.21 (SD = 1.97) in the pretest and 14.81 (SD = 1.53) in the posttest. The repeated measures ANOVA yielded non-significant main effects of gender ($F(1, 15) = 1.048$, $p = .322$, $\eta^2 = .06$) and condition ($F(1, 15) = 0.685$, $p = .421$, $\eta^2 = .04$). The gender-group interaction was statistically significant ($F(1, 15) = 6.819$, $p = .020$, $\eta^2 = .31$).

These findings suggest a gendered pattern in response to the gamification sequence. Overall, the gamification condition affected males' motivation more positively than in females. Female participants' motivation decreased notably when exposed to the gamified condition first, indicating that gamification elements may not have effectively engaged or motivated them. In contrast, male participants responded more positively, particularly when the standard condition preceded the gamified intervention.

5.7. Individual changes in motivation

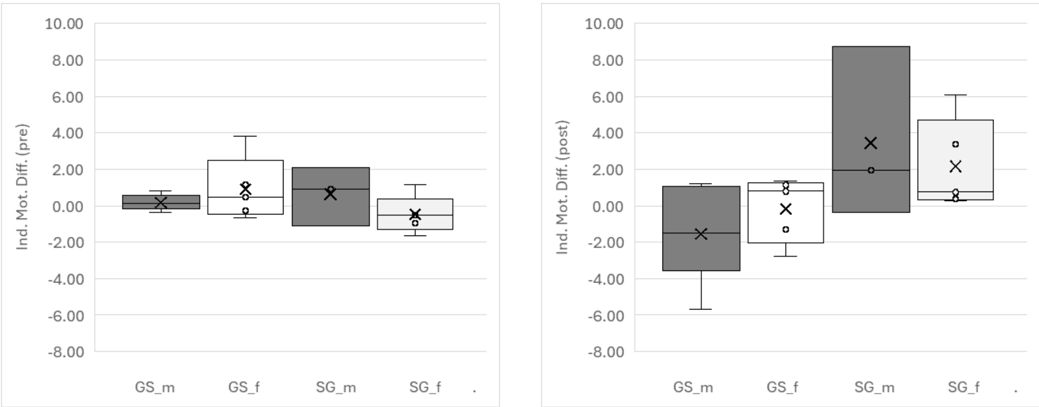

Figure 6. Differences in self-reported motivation for gamification-first (G-S) and standard-first (S-G) sequences: **(a)** Differences relative to pre-intervention scores for males (m) and females (w); **(b)** Differences relative to post-intervention scores across sessions for males and females.

The individual change in motivation in pre-intervention motivation scores reflect the expectations to the app to some degree. As shown in Figure 6a, there were only marginal differences in the self-reported motivation. A multivariate ANOVA did not report significant differences. The individual change in motivation in post-intervention motivation scores reflect the effects of using the app. As shown in Figure 6b, the motivation after using the gamified app were clearly higher than after using the standard app. A multivariate ANOVA reported significant differences for the condition ($F(1, 15) = 7.618$, $p = .015$, $\eta^2 = .34$) but not for gender or for the gender by condition interaction.

5.8. Correlation analysis

To investigate the direct relationship between motivation and performance, correlation analyses were conducted separately for male and female participants. The results highlight significant relationships between motivation scores (pre and post), time on task, and scores in both sessions.

5.8.1. *Male participants*

Independent from condition, overall, we found moderate but non-significant positive correlations between the motivation prior and after using the app in Session 1 ($r = .399$, $p = .288$) and Session 2 ($r = .337$, $p = .375$). Also, there was a substantial but non-significant positive correlation between the motivation prior to using the apps in both sessions ($r = .641$, $p = .063$), however, there was no correlation between the motivation after using the apps across sessions ($r = -.164$, $p = .673$). This suggests a tendency that participants have a certain level of motivation independent of their expectations (confirming the results on the individual motivational change reported in section 5.6.). The weak correlation of motivation after sing the apps in Sessions 1 and 2 may imply that the condition (gamified, standard) influenced the individual motivational level.

The relationships between achieved scores as well as time on task and motivation was analysed separately by condition. In the standard condition the correlation between score and motivation prior to using the app was r = -.185 (p = .633) and r = .043 (p = .912) after using the app. The relationship between time on task and motivation was r = -.187 (p = .630) prior to using the app and r = .219 (p = .572) after using the app. Overall, there was little to no effect of the motivational level and performance (scores and time on task) in males. In the gamification condition the correlation between score and motivation prior to using the app was r = .465 (p = .207) and r = .155 (p = .690) after using the app. The relationship between time on task and motivation was r = -.514 (p = .157) prior to using the app and r = -.100 (p = .798) after using the app. Overall, there was little to no effect of the motivational level and performance. This suggests that the gamification condition led to higher motivation in males and this, in turn, to higher scores. Notably, the motivation prior to using the app yielded a stronger relationship than after using the app. An explanation for this effect might be that not only the gamification experience but also the achievements (scores) could have influence post motivation. For time on task, we found an inverse relationship; the higher the motivation the shorter was the time on task. This suggests a possible tendency that highly motivated male participants worked faster. This pattern could reflect a trade-off where prolonged effort may not translate into improved performance, potentially due to factors such as inefficient strategies or cognitive overload. These correlations indicate a trend suggesting that for male participants, initial motivation levels may influence performance outcomes, and there is a notable trade-off in time on task across sessions. This implies that male learners who are initially highly motivated may spend less time on tasks yet achieve better performance, reflecting a more efficient use of their study time. This comprehensive interpretation incorporates the significant and non-significant findings from the other analyses as well, providing a nuanced understanding of the relationships between motivation and performance for male participants.

5.8.2. Female participants

Overall, we found string and significant positive correlations between the motivation prior and after using the app in Session 1 (r = .693, p = .026) and Session 2 (r = .797, p = .006). Also, there was a substantial and significant positive correlation between the motivation prior to using the apps in both sessions (r = .677, p = .031) and between the motivation after using the apps across sessions (r = .709, p = .022. These results suggest that female participants exhibited a stable motivational pattern across sessions, indicating that their motivation was less affected by external experimental conditions, such as gamification elements. This confirms the results on the individual motivational change reported in section 5.6., but also suggest that using the apps had less impact on post-session motivation in females compared to males.

The relationships between achieved scores as well as time on task and motivation was analysed separately by condition. In the standard condition the correlation between score and motivation prior to using the app was r = .409 (p = .241) and r = .421 (p = .226) after using the app. The relationship between time on task and motivation was r =.202 (p = .576) prior to using the app and r = .510 (p = .132) after using the app. As opposed to males, we found a strong positive effect of the motivational level on performance (scores and time on task) in the standard condition. In the gamification condition the correlation between score and motivation prior to using the app was r =.131 (p = .718) and r = .006 (p = .986) after using the app. The relationship

Accepted Manuscript Online. DOI: 10.17471/2499-4324/1378

between time on task and motivation was r = .529 (p = .115) prior to using the app and r = .326 (p = .358) after using the app.

Overall, the results for female participants showed a different pattern compared to males, with greater stability in motivation across sessions and a weaker impact of external conditions such as gamification. A moderate but non-significant trend suggested that more highly motivated female participants tended to achieve higher scores and spend more time on task, particularly in the standard condition. However, these trends should be interpreted with caution due to their lack of statistical significance. The consistency in motivational patterns over time may suggest a role for initial motivation in shaping engagement, but further research is needed to substantiate its influence on performance outcomes.

6. Discussion

The present study aimed to explore the impact of gamification on student engagement, motivation, and learning outcomes in the context of a physics-based educational game. By examining the effects of gamified and non-gamified (standard) conditions on male and female learners, the study sought to understand how these elements influence performance and motivation across different sessions.

6.1. Gender differences in motivation

Contrary to our initial hypothesis, the study found no significant overall gender differences in self-reported motivation scores before and after using the learning app across both sessions. However, significant within-group differences were observed, particularly among female participants. While males showed no significant changes in motivation across sessions, female learners exhibited a significant decline in motivation after using the learning app in both sessions. This effect was stronger in Session 2, suggesting a cumulative negative impact of the intervention on female learners' motivation. These findings indicate that while gamification did not differentially affect overall gender motivation levels, it had a stronger impact on motivational stability among female learners.

A closer examination of motivational trends revealed that females who transitioned from the standard to the gamified condition exhibited lower motivation scores, whereas male learners showed a more stable motivational pattern. These findings suggest that while gamification might initially engage female learners, this engagement does not sustain over time, possibly due to a perceived lack of relevance or appeal in the gamified elements. In contrast, males appeared to respond more consistently to gamification, suggesting potential differences in how gamification is perceived and valued by different genders. These findings align with prior research indicating that gender differences can influence learning motivation. Studies have shown that female students tend to demonstrate stronger self-regulation in online learning contexts, while male students may utilize more learning strategies and possess better technical skills (Puspitaningrum et al., 2021; Yu, 2021).

These differences underscore the multifaceted impact of gender on learning behaviours, emphasising the necessity for customised gamification strategies to address these variations. Conversely, when designed effectively, gamification has the potential to be universally beneficial for both genders (Ragusa et al., 2024). For instance, research has demonstrated that inclusive gamified approaches have the capacity to bridge gender gaps by integrating diverse challenges and rewards that appeal to a range of motivational factors. Such strategies emphasise equitable engagement, ensuring that both male and female learners remain motivated over time (Ragusa et al., 2024).

The observed differences highlight the crucial relationship between motivation and engagement. When motivation decreases, engagement in learning activities tends to decline, as evidenced by the reduced time on task for female learners in Session 2. In contrast, sustained motivation, as observed in male learners, was associated with improved performance over time. These insights underscore the necessity for the implementation of gender-sensitive gamification strategies that ensure long-term engagement for both genders.

6.2. Impact on performance

The hypothesis that gamification would lead to significant differences in learning performance between male and female learners was partially supported. No significant gender differences were observed in overall performance metrics such as time on task and scores, indicating that both genders performed similarly regardless of gamification. However, detailed analysis revealed that males tended to score higher in the gamified condition compared to the standard condition in session one. Conversely, females initially spent more time on tasks in the gamified condition, but this engagement decreased in session two.

These findings highlight that while gamification can enhance performance for male learners, its effects on female learners may diminish over time, necessitating a revaluation of how gamification elements are designed and implemented to maintain engagement for all learners. This observation aligns with research showing that gamification significantly contributes to academic participation and influences learners' engagement in gamified environments (Zaric et al., 2021; Özhan & Kocadere, 2019). Flores (2016) and Wei et. al. (2024) discuss the role of educational games in boosting academic achievement and confidence, emphasizing the need for structured and interactive frameworks to sustain learner engagement.

6.3. Interaction effects on learning outcomes

The study also explored the interaction effects between session sequence and condition on learning outcomes, with results partially supporting the hypothesis to some extent. The repeated measures ANOVA revealed significant interaction effects for males' scores and females' time on task. Specifically, males showed lower scores in the standard condition compared to the gamified condition, while females exhibited higher engagement initially in the gamified condition but less so over time. These interaction effects underscore the importance of considering both the sequence and condition in designing gamified educational interventions. For male learners, introducing gamification early on might enhance performance, while for female learners, maintaining engagement might require varied or adaptive gamification strategies over time. This finding is consistent with research by Özhan & Kocadere (2019) and Kostolányová & Klubal (2018), which indicate that the design of gamified learning environments significantly influences academic participation and engagement.

6.4. Correlation analysis

The correlation analysis provided additional insights into the relationships between motivation and performance. For male learners, initial motivation before session 2 showed a non-significant trend toward a negative correlation with performance in session 1. Furthermore, better performance in session 1 was associated with less time needed in session 2. While these trends were not statistically significant, they suggest that highly motivated male learners may tend to work more efficiently. In contrast, female learners showed strong, significant correlations between motivation scores across sessions, indicating stable motivational levels regardless of condition. The moderate but non-significant correlations between time on task across sessions for females suggest a tendency toward consistent engagement patterns, emphasizing the potential role of initial motivation in sustaining engagement and performance. While these findings align with previous research highlighting the importance of intrinsic motivation in fostering student engagement and learning outcomes, the non-significance of several key correlations suggests that further investigation is needed. Tan (2018) and Khatoon (2023) emphasize the role of intrinsic motivation in fostering student engagement and its significant impact on learning outcomes.

6.5. Implications for educational practice

These findings have significant implications for the design and implementation of gamified educational technologies. Understanding the differential impacts of gamification on male and female learners can inform the development of tailored strategies to enhance engagement and learning outcomes. For female learners, incorporating varied challenges, adaptive mechanics and personalized feedback could help sustain interest over time, addressing the observed decline in motivation. For male learners, early introduction of gamification may provide a consistent boost to performance. These strategies align with existing literature on personalized learning and gamification (Buckley & Doyle, 2014; Martí-Parreño et al., 2016). Gamification leverages game elements to make learning more interactive, enjoyable, and rewarding, thereby fostering students' intrinsic motivation to participate in educational activities (Martí-Parreño et al., 2016). Additionally, research suggests that intrinsic and extrinsic motivation can impact student participation and performance in online gamified learning interventions (Buckley & Doyle, 2014).

7. Conclusion

The Basketball Physics Challenge study offers valuable insights into the impact of gamification on physics learning, highlighting its potential to enhance engagement and performance. However, the effects of gamification vary across genders and over time, and it is therefore important to tailor gamified educational tools to the needs of diverse learner demographics if optimal effectiveness and educational outcomes are to be achieved. This study emphasises the importance of considering gender differences in designing gamified learning tools and demonstrates gamification's potential to sustain engagement in educational settings. However, the findings should be considered in the context of the study's limitations, including the use of a small sample size and a focus on a single secondary school, which may affect the generalizability of the results. Future research should involve larger, more diverse samples and address the reliance on self-reported motivation measures by incorporating objective data, such as behavioural and physiological indicators. By addressing these limitations, future studies can provide deeper insights and robust evidence to guide the development of inclusive and effective gamified educational technologies.

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