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Analyzing the Relationship between Emotional Intelligence and Conceptual Learning of Tenth-Grade Male Students through Virtual Mathematics Games Based on the APOS Theory

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Abstract

This study investigates the impact of virtual mathematics games, designed based on the Action, Process, Object, Schema (APOS) theory, on the Emotional Intelligence (EI) of tenth-grade male students in district 4 of Karaj, Iran. A quasi-experimental design with pre-test, post-test, and control group was employed, and 100 students were randomly assigned to experimental and control groups. The experimental intervention consisted of virtual mathematics games developed in alignment with the principles of APOS theory, aimed at enhancing various levels of conceptual understanding as well as students' cognitive and emotional engagement. Data were collected using the Bar-On EI inventory. The findings revealed that APOS-based interactive and cooperative mathematics games significantly improved students' self-awareness, emotional regulation, and social skills. In contrast, overexposure to competitive or violent digital games weakened emotional control and increased aggressive behaviors. These results highlight the crucial role of designing virtual mathematics games grounded in cognitive development frameworks such as APOS to foster both emotional and social growth among adolescents. The study provides valuable insights for mathematics teachers, parents, and policymakers, emphasizing that incorporating APOS-based cooperative games in educational settings can effectively strengthen EI while supporting healthier socio-emotional development.

Keywords: Cooperative virtual games, Emotional intelligence, Action, process, object, schema theory, Mathematics education, Educational technology.

1 | Introduction

In the contemporary era, Information and Communication Technology (ICT) has become one of the fundamental pillars of human life. Particularly among adolescents, digital tools such as smartphones, tablets,

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and computers are regarded as integral components of daily activities [1]. One of the most significant educational applications of these technologies is the use of virtual and video games, which, beyond their entertainment value, have the potential to enhance adolescents' cognitive, emotional, and social skills [2].

Adolescence is a sensitive period in cognitive and emotional development during which personality traits, behavioral patterns, and emotional capacities are formed. One of the most important psychological constructs during this stage is Emotional Intelligence (EI), defined as the ability to perceive, regulate, and manage one's own emotions and those of others. EI plays a crucial role in adolescents' academic achievement, social adjustment, and mental health [3]. Studies conducted in Iran indicate that online multiplayer educational games can improve students' social skills and cognitive abilities, and that EI contributes significantly to the promotion of mental health and effective learning [4], [5].

Recent research suggests that virtual mathematics games, when designed based on structured cognitive frameworks such as the Action, Process, Object, Schema (APOS) theory, provide effective opportunities to enhance both cognitive and emotional skills. APOS theory explains how learners progress from performing actions to understanding processes, conceptualizing objects, and ultimately integrating these concepts into complex cognitive schemas [6]. This framework can guide the design of interactive and collaborative mathematics games that foster students' self-awareness, emotional regulation, problem-solving abilities, and group collaboration skills [7]. Particularly in mathematics education, collaborative virtual games grounded in APOS theory can enhance conceptual learning through active student engagement and facilitate the interaction between cognitive and emotional competencies. In contrast, excessive use of digital games or exposure to violent games may reduce real-life social interactions, disrupt emotional regulation, and increase aggressive behaviors [8]. This contrast highlights the importance of purposeful and principled design of virtual mathematics games to maximize their positive effects on adolescents' learning and EI.

The concept of EI, first introduced by Salovey and Mayer [9] and later expanded by Goleman [10] and Bar-On [11], encompasses self-awareness, self-regulation, motivation, empathy, and social skills. Integrating APOS theory with collaborative educational mathematics games offers a structured approach to strengthening these competencies, guiding students from practical engagement (action) to deeper understanding (process), conceptual integration (object), and ultimately the formation of complex cognitive schemas (schema).

Given the mixed findings in the literature and the growing need for the purposeful use of technology in mathematics education, the present study aims to investigate the effects of APOS-based virtual games on EI and conceptual mathematics learning among tenth-grade male students in district 4 of Karaj. The main research question is: to what extent and in what ways do virtual games designed based on APOS principles influence students' EI and conceptual understanding of mathematics?

The findings of this study are expected to provide evidence-based insights for teachers, parents, and educational policymakers, facilitating the optimal use of virtual mathematics games in educational settings from both cognitive and emotional perspectives, and promoting deep and sustainable learning among male students.

2 | Literature Review

Over the past two decades, research has increasingly examined the psychological and educational effects of digital and virtual games on adolescents, particularly in relation to EI. EI is widely defined as the ability to perceive, regulate, and manage one's own emotions as well as those of others [3]. It has been recognized as a key factor in students' academic success, social adjustment, mental health, and interpersonal interactions [10].

Numerous studies have reported both positive and negative outcomes associated with digital game use. For instance, Granic, Lobel, and Engels [7] concluded that specific game genres especially strategic, simulation, and cooperative multiplayer games can promote social learning, emotional development, and cognitive growth by fostering skills such as empathy, cooperation, flexibility, and adaptive coping with challenging

situations. Similarly, Kuss and Griffiths [12] noted that although excessive gaming may be associated with emotional regulation difficulties and addictive behaviors, digital games can also function as emotional regulators, reducing symptoms of anxiety and depression. Nevertheless, violent or solitary games have been linked to adverse outcomes. Meta-analytic studies indicate that exposure to violent video games is associated with decreased empathy and increased aggression [8]. In contrast, non-violent and team-based games are associated with improved impulse control and enhanced emotional self-awareness [1].

Recent studies emphasize the role of contextual and moderating variables, including game type, cultural background, duration of gameplay, and gender. Empirical evidence suggests that adolescents who participate in online team-based games particularly collaborative mathematics games demonstrate higher levels of emotional regulation, self-awareness, and conceptual mathematics learning compared to solitary players [13], [14].

In Iran, Nabavi et al. [15] investigated the relationship between computer games and EI among students. Their findings revealed a significant association between students' EI and both the type of games they preferred and the games they most frequently played. Salehi [16] reported that computer games had a significant effect on emotional expression and self-control among female middle school students. Moreover, Nourmohammadi et al. [17] demonstrated that social game-based interventions had a substantial impact on emotional self-awareness and social skills among students who were victims of domestic violence. These findings suggest that while single-player games are often associated with emotional regulation difficulties, multiplayer environments tend to foster positive social behaviors and interpersonal skills.

Yousefi et al. [18], in a study entitled the effect of flipped classroom instruction on ninth-grade students' mathematics performance based on APOS theory, examined changes in students' learning processes and analyzed their progression across different learning levels. Their results indicated a shift from surface learning levels (action and process) toward deeper levels (object and schema). Similarly, Dugnol-Menéndez et al. [19], in a study titled design strategies for educational escape games for stealth classroom assessment in primary education, explored the application of educational escape games for formative and unobtrusive assessment. They concluded that escape games, through the integration of storytelling, puzzles, and group collaboration, create engaging and safe environments for active learning and natural interaction. These studies underscore the growing importance of game-based approaches in educational contexts.

Integrating APOS theory into the design of virtual mathematics games provides a structured framework for enhancing both EI and conceptual learning. According to this theory, students are guided from practical engagement (action) to deeper understanding (process), conceptualization (object), and ultimately the formation of complex cognitive schemas (schema). APOS-based mathematics games can more effectively foster self-awareness, emotional regulation, empathy, social skills, and conceptual mathematics learning.

Collectively, this body of evidence suggests that while unregulated or violent games may pose psychological risks, collaborative and APOS-based games represent powerful tools for enhancing EI and conceptual mathematics learning among male adolescents.

3 | Theoretical Framework

3.1 | Concept and Components of Emotional Intelligence

EI refers to the ability to identify, assess, manage, and utilize one's own emotions as well as those of others, and is considered a critical component of students' psychological and social development [3]. Bar-On [20] conceptualized EI as a set of skills and abilities to cope with environmental and interpersonal pressures. According to the Bar-On model, EI encompasses five major domains: intrapersonal (self-awareness, assertiveness), interpersonal (empathy, social responsibility), stress management, general mood, and adaptability (problem-solving, reality assessment).

Gilar-Corbi [21] demonstrated that adolescents who participate in interactive and group-based games perform better in the interpersonal and adaptability components of EI. He emphasized that the type of game and the interactive environment can either enhance or limit emotional development. Similarly, Goleman [10] highlighted the significance of EI in academic success, emotional regulation, and social relationships, identifying five core components: self-awareness, self-regulation, motivation, empathy, and social skills, all of which can be strengthened through social and interactive experiences, such as team-based games [22].

Integrating APOS theory provides a structured framework to demonstrate how virtual games can enhance these components. Students progress from the action stage (engaging in simple activities) to the Process stage (understanding strategies and emotional dynamics), then to the object stage (conceptualizing social-emotional and mathematical patterns), and finally to the schema stage (integrating knowledge and emotional skills into complex cognitive structures).

3.2 | Virtual Games and Emotional and Mathematical Learning

Virtual games, as immersive and interactive environments, require active engagement with both game content and other players. Online multiplayer mathematics games demand cooperation, quick decision-making, and emotional regulation.

Salehi [16] found that computer-based virtual games significantly influence EI and its components, including self-awareness, self-management, social awareness, and relationship management. By applying APOS principles, mathematics games can be designed to guide students from simple actions to complex understandings of mathematical and emotional patterns, simultaneously fostering conceptual learning and cognitive-emotional development. Examples of proposed mathematics games for tenth grade:

I. Math quest (team-based math puzzle): solving geometry and algebra problems within a story-driven group challenge; enhances problem-solving and collaboration.

II. Escape the math maze: unlock mathematical paths by solving equations and inequalities; strengthens logical thinking and rapid decision-making.

III. Fraction battle royale: students compete in groups to solve fraction and percentage problems; promotes conceptual learning and social interaction.

IV. Algebra adventure: solve multi-step equations to progress through game stages; reinforces algebraic concepts and problem-solving strategies.

V. Geometry builder: construct geometric shapes and calculate perimeter and area to achieve game objectives; strengthens geometric understanding and team coordination.

These games can be systematically aligned with the APOS stages of APOS theory, promoting simultaneous development of mathematical learning and EI.

3.3 | Uses and Gratifications Theory

The Uses and Gratifications Theory (UGT) examines users' motivations and satisfaction in media consumption, positing that individuals actively seek media to satisfy cognitive, emotional, and social needs, or to escape reality. Applied to digital games, UGT demonstrates that adolescents choose games that fulfill emotional and social needs, such as achievement, competition, social belonging, or emotional release.

Combining UGT with APOS theory allows the design of virtual games that guide adolescents through different stages of emotional learning:

I. Action: participation and achievement of immediate goals (cooperation, game challenges).

II. Process: reflection and analysis of choices and emotional responses.

III. Object: internalization of emotional patterns and social rules.

IV. Schema: integration of emotional understanding into personal and social competencies.

3.4 | Interactive Media and Emotional Model

Digital games, as interactive media, exert a bidirectional influence on users' emotions: while emotional experiences arise through gameplay (e.g., excitement from winning or frustration from failure), the ability to manage these emotions improves over time. Louie and Baitenz [23] found that narrative-driven games with high emotional engagement (e.g., life is strange and journey) significantly enhance empathy and the understanding of others' emotions.

Through APOS theory, interactive games can be structured so that students systematically progress through cognitive and emotional stages, transforming gameplay from mere entertainment into a pathway for emotional growth, self-regulation, and social skill development.

3.5 | Bar-On Questionnaire

Previous studies (Salehi [16], Adachi [24]) validated the adolescent version of the Bar-On EI questionnaire using Cronbach's alpha ($\alpha = 0.89$) and confirmatory factor analysis. The adolescent version includes 90 items across 15 subscales, using a 5-point Likert scale.

Table 1. Core components of the bar-on questionnaire.

No.	EI Component	Number of Items
1	Emotional self-awareness	6
2	Emotional expression	6
3	Self-esteem	6
4	Social awareness	6
5	Empathy	6
6	Interpersonal relationships	6
7	Realistic decision-making	6
8	Problem-solving	6
9	Stress tolerance	6
10	Impulse control	6
11	Flexibility	6
12	Social responsibility	6
13	Optimism	6
14	Happiness	6
15	Self-motivation	6

Sample items: "I know exactly why i am upset", "I remain calm in stressful situations", "I plan my goals carefully."

4 | Methodology

To investigate the effects of APOS-based collaborative virtual mathematics games on EI and conceptual mathematics learning among tenth-grade male students in district 4 of Karaj, relevant theories and studies on educational mathematics games and interactive instructional models were first reviewed.

The population consisted of all tenth-grade male students in district 4 during the 2024–2025 academic year. From this population, 100 students were selected using cluster random sampling and were randomly assigned to an experimental group ($n = 50$) and a control group ($n = 50$). The study employed a quasi-experimental design with pre-test and post-test measurements and a control group. The experimental group participated in APOS-based virtual mathematics game sessions, whereas the control group received conventional mathematics instruction.

The experimental intervention consisted of APOS-designed virtual mathematics games, structured to guide students from simple to more complex levels of mathematical learning and emotional skill development. The intervention followed the APOS stages:

I. Action stage: students engaged in solving short mathematical problems within the game and had initial interactions with the virtual environment and other players.

II. Process stage: students recorded and analyzed their feedback regarding mathematical and emotional decisions (e.g., evaluating equation-solving strategies or decisions to collaborate in group problem-solving).

III. Object stage: mathematical concepts and emotional skills, such as self-regulation and empathy, were internalized through game activities.

IV. Schema stage: students acquired the ability to integrate mathematical concepts and emotional skills through solving more complex problems and participating in online group games.

Sample tenth-grade mathematics games:

I. Math land: an adventure game where students solve algebra, function, and statistics problems progressively and competitively.

II. Equation quest: a group-based game for solving equations and inequalities collaboratively to earn points.

III. Function fortress: a collaborative online game focusing on functions and graph problems.

IV. Geometry battle: an interactive game with geometric and coordinate puzzles, requiring students to compete or cooperate.

The games were categorized into three types:

I. Interactive games (e.g., math land, geometry battle) – focused on exploration, creativity, and individual interaction with mathematical problems.

II. Competitive games (e.g., equation quest) – emphasized individual and team performance in solving mathematics problems within structured competition.

III. Collaborative games (e.g., function fortress) – emphasized group cooperation, problem-solving, and team decision-making.

4.1 | Data Collection Instruments

I. EI: the Bar-On EI questionnaire with 15 subscales and a 5-point Likert scale.

II. Conceptual mathematics learning: a 10-item standardized test designed based on the tenth-grade mathematics curriculum and APOS learning levels, rated on a 5-point Likert scale.

III. Use of virtual games: a 15-item questionnaire assessing the type, duration, and style of gameplay.

Content and face validity of the questionnaires were confirmed by three faculty members in Educational Sciences and two faculty members in Psychology. Structural validity was verified in previous studies through exploratory and confirmatory factor analyses [16]. Reliability was assessed using Cronbach's alpha, yielding $\alpha = 0.87$ for the Bar-On questionnaire and $\alpha = 0.79$ for the virtual game usage questionnaire, indicating acceptable reliability.

4.2 | Intervention Procedure

An introductory session was conducted before the intervention to familiarize students with the research objectives and procedures for participating in the games. The experimental group then participated in the APOS-designed mathematics games for four weeks, with two 90-minute sessions per week held in the school environment under the supervision of a digital education instructor and school counselor. The control group received standard mathematics instruction without game-based intervention.

5 | Data Analysis

This study employed a quasi-experimental design with a pre-test and post-test and a control group. Quasi-experimental designs are widely used in educational research as they allow comparison between groups under

different conditions. In this study, the educational intervention involved APOS-based virtual mathematics games.

Descriptive statistics, including means and standard deviations, were calculated for each variable. Paired-sample t-tests and Analysis of Covariance (ANCOVA) were used to compare pre-test and post-test scores. The effect size was estimated using Cohen's d. Pearson correlation analysis was conducted to examine the relationship between game types (interactive, competitive, collaborative) and the components of EI and conceptual mathematics learning. Multiple regression analysis was applied to predict EI and conceptual learning based on game type.

5.1|Descriptive Statistics

The means and standard deviations of EI and mathematics learning scores for each game type are presented in *Table 2*:

Table 2. Means and standard deviations of EI and mathematics learning by game type.

Game Type	Mean EI	SD	Mean Math Learning	SD
Collaborative	4.38	0.42	4.25	0.40
Interactive	3.95	0.38	3.90	0.35
Competitive	3.20	0.41	3.05	0.42

As shown, students participating in collaborative mathematics games obtained the highest scores in EI and mathematics learning, followed by interactive games, while competitive games had the lowest impact.

5.2|Analysis of Covariance

To control for pre-test effects, ANCOVA was performed, using pre-test scores for EI and mathematics learning as covariates.

Table 3. ANCOVA for post-test scores of EI and mathematics learning.

Dependent Variable	F	p-value
EI	14.67	<0.001
Mathematics learning	12.21	<0.001

The post-test results indicate that, even after controlling for pre-test scores, collaborative games had the greatest effect.

5.3|Pearson Correlation Analysis

To examine the relationship between game types and EI components, Pearson correlation coefficients were calculated.

Table 4. Pearson correlation between EI components and game types.

EI Component	Collaborative	Interactive	Competitive
Emotional self-awareness	0.55	0.38	0.18
Impulse control	0.50	0.35	0.15
Empathy	0.57	0.42	0.20
Interpersonal skills	0.60	0.45	0.22
Problem-solving	0.52	0.40	0.19

Collaborative games showed the strongest correlations with EI components, especially empathy ($r = 0.57$) and interpersonal skills ($r = 0.60$). Competitive games showed the weakest correlations, indicating a lower impact on emotional development.

5.4 | Multiple Regression Analysis

Multiple regression analyses were conducted to predict EI and mathematics learning based on game type, with collaborative, interactive, and competitive games as predictor variables.

Table 5. Multiple regression predicting EI by game type.

Predictor	β	t	p-value
Collaborative	0.52	6.11	<0.001
Interactive	0.38	4.32	<0.001
Competitive	0.09	1.22	0.226

The model explained 42% of the variance in EI ($R^2 = 0.42$).

Table 6. Multiple regression predicting mathematics learning by game type.

Predictor	β	t	p-value
Collaborative	0.48	5.90	<0.001
Interactive	0.35	3.88	<0.001
Competitive	0.12	1.45	0.150

The model explained 38% of the variance in mathematics learning ($R^2 = 0.38$).

These results indicate that collaborative and interactive games are significant predictors of EI and mathematics learning, with collaborative games exhibiting the strongest effect. Competitive games showed no significant effect. Overall, collaborative and interactive virtual games positively and significantly influence EI components and mathematics learning, with collaborative games being the most effective.

5.5 | Action, Process, Object, Schema Theory Progress Analysis

I. Action stage: students displayed immediate, observable reactions during gameplay. Collaborative and interactive games elicited empathy, emotional control, and cooperative problem-solving, whereas competitive games emphasized individual victory and impulsive responses.

II. Process stage: students began internalizing experiences and regulating emotions consciously. In collaborative and interactive games, players learned to manage emotions, consider teammates' feedback, and engage in collective decision-making. Mean process scores were: collaborative = 4.35, interactive = 3.95, competitive = 3.22 ($F = 13.45$, $p < 0.001$).

III. Object stage: emotional processes became stable cognitive constructs. For example, empathy became a consistent skill for understanding others beyond the game. Problem-solving transformed into transferable cognitive objects. Mean object scores: collaborative = 4.40, interactive = 4.05, competitive = 3.25 ($F = 15.12$, $p < 0.001$).

IV. Schema stage: skills and concepts were integrated into a coherent structure, forming an "EI schema" encompassing empathy, interpersonal skills, emotional control, and problem-solving. Mean schema scores: collaborative = 4.42, interactive = 4.08, competitive = 3.28 ($F = 16.33$, $p < 0.001$).

V. Summary of APOS analysis: collaborative mathematics games aligned most closely with the APOS stages, progressing from immediate reactions in the action stage to a structured EI and conceptual learning framework in the schema stage. Interactive games followed a similar but weaker path, while competitive games largely remained at the action stage, exhibiting minimal impact on EI and conceptual learning.

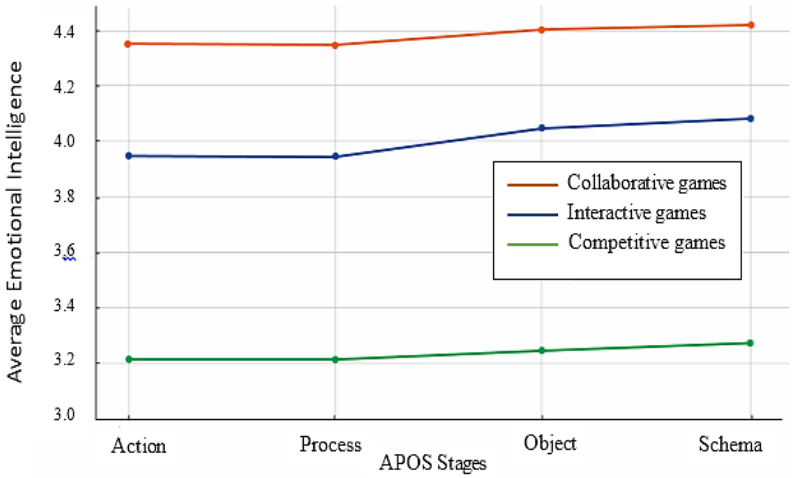

Fig. 1. Student progress across APOS theory stages based on mathematics game types.

6 | Conclusion

The findings of this study indicate that virtual mathematics games, particularly those that are collaborative and interactive, play a prominent role in enhancing EI and conceptual mathematics learning among 10th-grade male students. Statistical analyses revealed that students exposed to collaborative and interactive mathematics games, such as DragonBox Algebra 12+, Prodigy math game, and construction-based environments like Minecraft Education Edition, demonstrated significant improvements not only in EI components empathy, emotional regulation, emotional self-awareness, and interpersonal skills—but also in their understanding of mathematical concepts. These outcomes can be interpreted within the framework of APOS theory:

I. Action stage: mathematics games provided opportunities for immediate emotional responses and practical problem-solving.

II. Process stage: students internalized problem-solving strategies and organized their emotions and thoughts through collaboration and interaction.

III. Object stage: mathematical concepts and emotional skills, such as empathy and impulse control, were consolidated into stable cognitive structures.

IV. Schema stage: these experiences were integrated into a coherent framework, stabilizing both conceptual learning in mathematics and emotional development.

The results also indicated that competitive games, while capable of generating short-term motivation, had weaker effects on both conceptual mathematics learning and EI compared to collaborative games. This aligns with the findings of Salonius and Gelfond [25], who reported that excessive competitive gaming may lead to negative emotions and reduced emotional control.

Overall, these results suggest that purposeful use of virtual mathematics games, especially APOS-based collaborative and interactive games, can serve as an effective tool to:

I. Enhance high school students' conceptual understanding of mathematics.

II. Strengthen key components of EI.

III. Promote healthier social interactions within the school environment.

Educational policymakers, school counselors, and mathematics teachers are encouraged to integrate these games as complementary tools alongside traditional teaching methods to simultaneously improve academic performance and foster students' social and emotional skills.

6.1 | Limitations and Challenges

Measurement tools: conceptual mathematics learning was assessed using researcher-developed tests, and EI was measured via the Bar-On questionnaire. Although these tools demonstrated adequate validity and reliability, incorporating diverse instruments (e.g., clinical interviews or qualitative analysis of gameplay performance) could enrich the findings.

I. Game selection: only a limited number of games—DragonBox Algebra 12+, Prodigy math game, and Minecraft Education Edition—were employed. Hence, the results may not generalize to all virtual mathematics games.

II. Intervention duration: the intervention lasted four weeks, which may not capture long-term changes in EI and conceptual learning.

III. Sample population: the study population was restricted to 10th-grade male students in district 4 of Karaj, limiting generalizability to other regions, grade levels, or female students.

IV. External factors: variables such as family support, students' prior experience with digital games, and individual learning motivation were not fully controlled and could have influenced the results.

6.2 | Recommendations

For researchers:

I. Future studies should integrate quantitative and qualitative methods to better capture cognitive and emotional processes during gameplay.

II. Investigate the impact of mathematics games over longer periods (e.g., one semester or academic year) to assess the sustainability of effects.

III. Compare the effects of mathematics games across male and female students and different grade levels to examine developmental and gender differences.

For educational policymakers:

I. Design and localize mathematics games aligned with the Iranian curriculum based on the APOS framework to simultaneously enhance conceptual learning and EI.

II. Include teacher training workshops on integrating educational digital games with traditional instruction.

For school counselors and mathematics teachers:

I. Utilize collaborative and interactive mathematics games as complementary classroom tools, especially for challenging concepts such as algebra and geometry.

II. Focus on the emotional aspects of games, guiding students to develop empathy, cooperation, and emotional regulation alongside problem-solving skills.

For families:

Monitor and manage the duration and type of digital games, directing children toward educational mathematics games rather than purely competitive or violent games.

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Authors' Contributions

All aspects of the research and manuscript preparation were carried out by the author. The author has read and approved the final version of the manuscript.

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Data Availability

All data are included in the text.

Conflict of Interest

The authors declare no conflict of interest.

Consent for Publication

The author has given consent for the publication of this manuscript.

Ethics Approval and Consent to Participate

This study does not involve any research conducted on human participants or animals.

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