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Toward a Conceptual Extension of TPACK through Game-Based and Simulation-Supported Learning

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Abstract

This study examines the impact of game-based and simulation-supported learning environments on students' academic achievement, engagement, and technological pedagogical competencies in social studies education. Despite the increasing integration of digital technologies in education, the pedagogical effectiveness of combining game-based and simulation-supported approaches remains underexplored, particularly in relation to established theoretical frameworks such as Technological Pedagogical Content Knowledge (TPACK). To address this gap, the study employed a mixed-method research design involving 64 secondary school students divided into experimental and control groups. Quantitative data were collected through achievement tests, TPACK scales, and engagement measures, while qualitative data were obtained from interviews, observations, and reflective feedback. The findings indicate that students in the experimental group demonstrated significantly higher levels of academic achievement and engagement compared to those in traditional learning environments. Specifically, the experimental group showed a significant increase in academic achievement ($\Delta = 19.30$, $p < .001$), whereas the control group showed a limited and non-significant improvement ($\Delta = 6.40$, $p > .05$). Beyond the empirical findings, the study contributes to the literature by proposing the TPACK-GSL model as a preliminary conceptual extension of the TPACK framework. Drawing on evidence derived from students' learning outcomes and experiences in game-based and simulation-supported learning environments, the model suggests that technology integration may be understood as a dynamic and context-responsive process shaped by interaction, experiential learning, and pedagogical design. While the proposed model provides initial theoretical insights into technology-supported learning, further research is needed to validate and refine the model across different educational contexts, disciplines, and instructional settings.

Keywords: Game-based learning, simulation-supported learning, TPACK, digital pedagogy, social studies education

Introduction

The rapid advancement of digital technologies has significantly transformed educational practices, promoting learner-centered pedagogies and the development of 21st-century skills such as critical thinking, collaboration, and digital literacy (Redecker, 2017; Voogt et al., 2013; Yusuf et al., 2025). In this transformation, integrating technology effectively into teaching and learning processes has become a central concern in educational research. Among innovative approaches, game-based learning (GBL) and simulation-supported learning have gained

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increasing attention due to their potential to foster engagement, experiential learning, and problem-solving skills (Clark et al., 2016; Makransky & Petersen, 2021; Plass et al., 2015).

Game-based learning provides interactive and motivating environments that enhance student engagement and learning outcomes, while simulations enable learners to explore complex systems and real-world scenarios through experiential and inquiry-based processes (Gee, 2003; Radianti et al., 2020; Squire, 2013). Recent studies suggest that these approaches can support higher-order thinking, collaboration, and decision-making when effectively integrated into instructional design (Dede et al., 2018; Makransky & Petersen, 2021). However, the effectiveness of these approaches depends not solely on the availability of digital tools, but on how they are pedagogically structured and implemented within classroom contexts (Koehler & Mishra, 2009; Scherer et al., 2019).

Despite the growing body of research, game-based and simulation-supported learning are often examined separately, with limited attention to their combined pedagogical impact. Furthermore, existing studies predominantly focus on student outcomes such as achievement, motivation, and engagement, while neglecting the underlying pedagogical frameworks that shape technology integration (Clark et al., 2016; Radianti et al., 2020). In this regard, the Technological Pedagogical Content Knowledge (TPACK) framework offers a comprehensive lens for understanding how teachers integrate technology into teaching practices (Koehler & Mishra, 2009). However, TPACK has been criticized for its limited capacity to capture dynamic, context-dependent, and interactive learning environments such as those created through game-based and simulation-supported approaches (Angeli & Valanides, 2014; Scherer et al., 2019). Despite these advancements, four critical gaps remain in the literature. First, existing studies tend to examine game-based learning and simulation-supported learning separately rather than as integrated pedagogical approaches (Clark et al., 2016; Radianti et al., 2020). Second, the majority of research focuses primarily on student outcomes such as achievement and motivation while paying limited attention to how these environments reshape pedagogical frameworks such as TPACK (Plass et al., 2015; Makransky & Petersen, 2021). Third, the application of these approaches in social studies education remains underexplored despite the discipline's emphasis on decision-making and inquiry-based learning (Squire, 2013; Dede et al., 2018). Finally, TPACK has been criticized for its relatively static and teacher-centered structure, which may not adequately capture dynamic and interaction-based digital learning environments (Angeli & Valanides, 2014; Scherer et al., 2019).

Accordingly, this study aims to address these gaps by examining how game-based and simulation-supported learning environments influence student outcomes and by exploring their implications for extending existing interpretations of the TPACK framework within social studies education.

Unlike traditional interpretations of TPACK that primarily conceptualize technology integration as a structured interaction among knowledge domains, the findings of this study suggest that technology integration may also be understood as a dynamic, interaction-driven, and context-responsive process shaped through experiential learning environments. In this respect, the proposed TPACK-GSL model offers a preliminary conceptual extension to ongoing discussions on dynamic TPACK models by highlighting learner participation, feedback processes, and collaborative interaction as potentially important dimensions of technology-supported learning.

Research Questions

This study was guided by the following research questions:

1.How do game-based and simulation-supported learning environments influence students' academic achievement and engagement in social studies education?

2.How do students perceive and experience game-based and simulation-supported learning environments?

3.How do the findings contribute to a preliminary conceptual extension of the TPACK framework?

Literature Review & Theoretical Framework

Game-based learning not only enhances engagement and cognitive skill development in digital education contexts, but also provides a conceptual foundation for understanding how structured game mechanics can be aligned with pedagogical objectives. Building on these principles, the following section examines the theoretical underpinnings that explain why and how game-based learning environments facilitate meaningful learning experiences.

Game-Based Learning in Digital Education

Game-based learning (GBL) has increasingly been recognized as an effective instructional approach that enhances student engagement, motivation, and learning outcomes within digital learning environments (Al-Sindi et al., 2023; Clark et al., 2016; Plass et al., 2015). By incorporating interactive elements such as feedback systems, challenges, and immersive environments, GBL supports active participation and fosters higher-order thinking skills, including problem-solving and decision-making (Dede et al., 2018; Gee, 2003; Szilágyi et al., 2024).

Recent studies emphasize that GBL can create meaningful and learner-centered experiences when pedagogically aligned with instructional goals (Mposula & Oyetade, 2025). However, despite its potential, research also highlights that poorly designed game-based environments may lead to superficial engagement rather than deep conceptual understanding (Clark et al., 2016; Fawns, 2022). This suggests that the effectiveness of GBL depends not only on the presence of game elements but also on their pedagogical integration within broader instructional frameworks. However, these studies largely overlook how game mechanics interact with pedagogical decision-making processes, indicating a need for a more integrated theoretical perspective.

Simulation-Supported Learning and Experiential Pedagogy

Simulation-supported learning extends experiential learning by enabling learners to explore complex systems and real-world scenarios in controlled digital environments (Radianti et al., 2020; Makransky & Petersen, 2021). Through simulations, students can test hypotheses, manipulate variables, and observe outcomes, thereby promoting deeper conceptual understanding and transferable skills (Falloon, 2020; Makransky & Petersen, 2021).

Recent research further indicates that simulation-based environments enhance decision-making and cognitive engagement, particularly in interdisciplinary learning contexts (Martín-Rodríguez & Madrigal-Cerezo, 2025). However, similar to GBL, simulations are not inherently effective. Without appropriate scaffolding, learners may experience confusion or cognitive overload, limiting their educational value (Radianti et al., 2020; Fawns, 2022). These findings highlight the importance of structured pedagogical design in maximizing the benefits of simulation-supported learning.

TPACK and the Challenges of Technology Integration

The Technological Pedagogical Content Knowledge (TPACK) framework provides a widely used model for understanding how teachers integrate technology into teaching practices

(Koehler & Mishra, 2009; Voogt et al., 2013). It conceptualizes effective teaching as the intersection of technological, pedagogical, and content knowledge domains.

Despite its widespread adoption, TPACK has been criticized for its limited ability to capture dynamic and context-dependent learning environments (Angeli & Valanides, 2014; Scherer et al., 2019). More recent studies argue that technology integration should be understood as a fluid and evolving process shaped by interaction, context, and learner engagement (Agbasi et al., 2026; Fawns, 2022). This limitation becomes particularly evident in game-based and simulation-supported environments, where learning emerges through interaction, experimentation, and feedback rather than linear instructional processes. More specifically, TPACK has been critiqued on four key dimensions. First, it is often treated as a static framework, failing to capture the dynamic nature of learning environments. Second, it lacks contextual sensitivity, as it does not fully account for discipline-specific pedagogical needs such as those in social studies. Third, measurement of TPACK remains problematic due to overlapping constructs. Finally, the framework tends to emphasize teacher knowledge while underrepresenting learner interaction and engagement.

Toward an Integrated and Contextual Model

While existing literature highlights the effectiveness of GBL, simulation-based learning, and TPACK, these constructs are often examined in isolation. Current research tends to focus either on student outcomes or teacher competencies, without sufficiently addressing the dynamic relationships between instructional design, technological affordances, and learner engagement (Martín-Rodríguez & Madrigal-Cerezo, 2025; Vashchuk, 2024).

Drawing on constructivist and experiential learning perspectives, learning can be understood as an interactive and context-dependent process shaped by participation, feedback, and reflection (Dede et al., 2018; Fawns, 2022). From this perspective, digital learning environments may support collaborative knowledge construction through interaction and engagement.

Taken together, these strands of literature suggest that technology integration in contemporary learning environments cannot be adequately explained through static or isolated instructional models. Game-based learning emphasizes participation and engagement, simulation-supported learning highlights experiential and decision-oriented processes, and dynamic interpretations of TPACK stress the contextual and evolving nature of technology integration. The convergence of these perspectives provides the conceptual foundation for the proposed TPACK-GSL model, which positions learning as an interactive, participatory, and context-responsive process.

Building on these perspectives, this study proposes a preliminary conceptual model (TPACK-GSL) derived from the findings, which extends the traditional TPACK framework by incorporating the interactive, experiential, and context-responsive dimensions of game-based and simulation-supported learning.

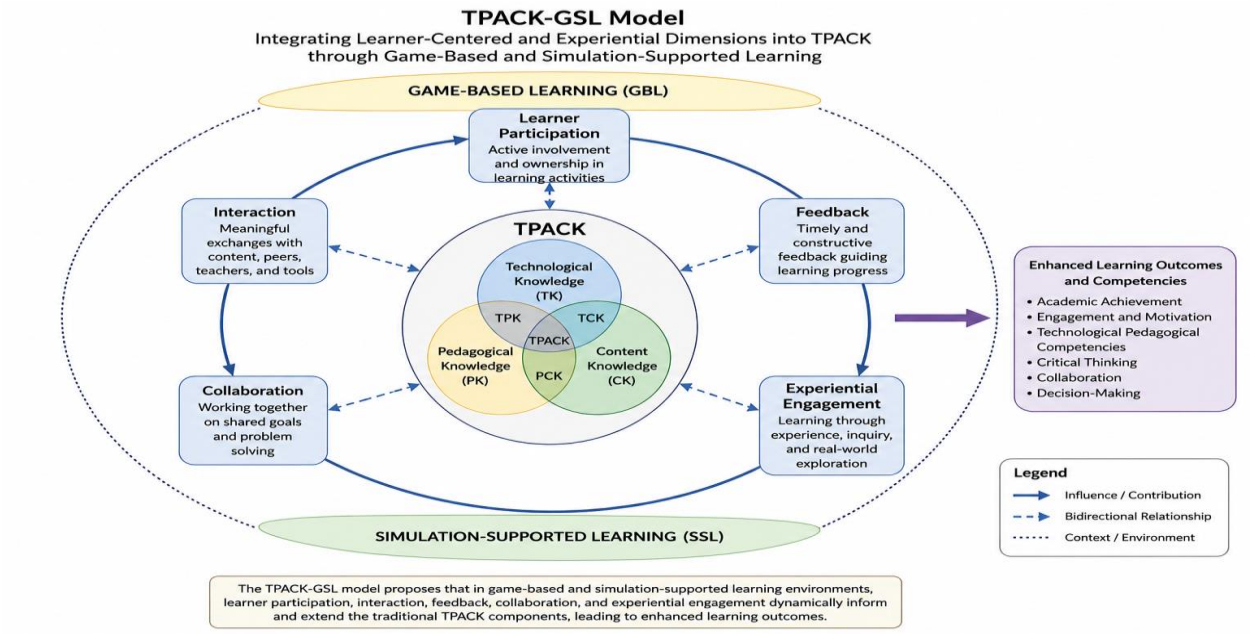


Figure 1

The proposed TPACK-GSL model

Method

Research Design

This study employed a mixed-method research design to examine how game-based and simulation-supported learning environments influence students' learning outcomes and explore their implications for extending existing interpretations of the TPACK framework. Mixed-method approaches are particularly effective in capturing both measurable outcomes and in-depth perspectives, allowing for a comprehensive understanding of complex educational phenomena (Creswell & Creswell, 2017). This study followed a convergent mixed-method design, in which quantitative and qualitative data were collected simultaneously, analyzed separately, and then integrated during interpretation. The study followed a quasi-experimental design complemented by qualitative data collection. The quantitative component aimed to measure the effects of the intervention on students' achievement, engagement, and technological pedagogical competencies, while the qualitative component explored students' experiences and perceptions within game-based and simulation-supported learning environments. Integration was achieved through triangulation, comparing quantitative results with qualitative themes.

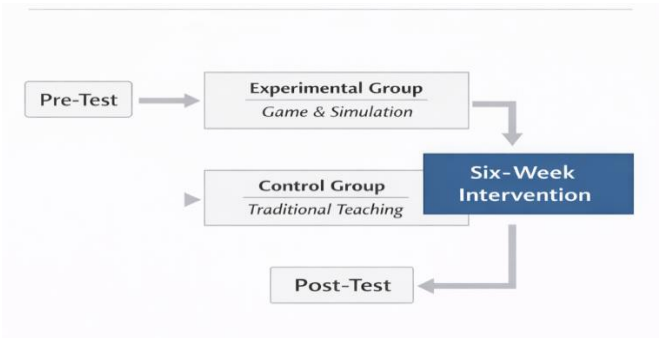


Figure 2

Research design of the study

Participants and Context

The study was conducted with 64 students enrolled in social studies courses at the secondary school level. Participants were divided into an experimental group (n = 32) and a control group (n = 32). The assignment of students to groups was based on existing classroom structures to maintain ecological validity. Participants were aged between 12 and 13 years (M = 12.6). The study was conducted in a public secondary school, and all students were enrolled in the 7th grade. Instruction was delivered by the same teacher to ensure consistency across groups. Students had basic digital literacy skills but limited prior experience with game-based or simulation-supported learning.

The experimental group participated in game-based and simulation-supported learning activities, while the control group received traditional instruction based on teacher-centered methods and textbook-oriented practices.

The instructional intervention was implemented over a six-week period, during which the experimental group engaged in interactive digital learning environments, including scenario-based simulations, educational games, and collaborative problem-solving tasks. These activities were aligned with the social studies curriculum and were designed to enhance students' engagement, decision-making, and conceptual understanding.

The learning environment integrated various digital tools and platforms to support interactive and experiential learning. This context enabled the examination of how different instructional approaches influenced students' academic achievement, engagement, and technological pedagogical competencies. The structured implementation of game-based and simulation-supported activities provided students with sufficient opportunities to engage with the learning environment and demonstrate measurable changes in learning outcomes.

Table 1
Participants and data collection overview

	Participants	Instruction Type	Data Collection Tools
Experimental Group	32 students	Game-based & Simulation-supported learning	Achievement test, TPACK scale, interviews
Control Group	32 students	Traditional instruction	Achievement test
Total	64 students	–	Quantitative + Qualitative data

Data Collection

Multiple data collection methods were employed to enable methodological triangulation and to provide a comprehensive understanding of students' learning experiences in game-based and simulation-supported environments. This approach allowed the study to capture both measurable learning outcomes and in-depth insights into student engagement, interaction, and decision-making processes.

The measurement instruments used in this study were selected and developed based on established procedures to ensure validity and reliability. The academic achievement test was developed by the researchers in alignment with the social studies curriculum and consisted of 25 multiple-choice items measuring students' conceptual understanding and higher-order thinking skills. To ensure content validity, the test items were reviewed by experts in social studies education and educational measurement, and necessary revisions were made. A pilot study was conducted, and the internal consistency of the test was calculated using Cronbach's alpha, yielding a reliability coefficient of $\alpha = .82$.

Students' technological pedagogical content knowledge (TPACK) was measured using a scale adapted from Schmidt et al. (2009), which included seven subdimensions: technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), pedagogical content knowledge (PCK), and technological pedagogical content knowledge (TPACK). A sample item from the scale is: "I can use technology to support my learning." The internal consistency coefficient of the scale in this study was calculated as $\alpha = .85$.

Student engagement was measured using a scale based on the framework proposed by Fredricks et al. (2004), which conceptualizes engagement as behavioral, emotional, and cognitive. The reliability coefficient was found to be $\alpha = .87$.

Quantitative data were collected using an academic achievement test, a TPACK scale, and a student engagement scale. The achievement test was designed in alignment with the social studies curriculum to assess students' conceptual understanding before and after the intervention. The TPACK scale was used to examine students' technological and pedagogical competencies, while the engagement scale measured students' behavioral, emotional, and cognitive involvement in the learning process. Pre-test and post-test measures were administered to both experimental and control groups to evaluate the impact of the instructional intervention.

To complement the quantitative findings, qualitative data were collected through semi-structured student interviews, classroom observations, and reflective feedback forms. Semi-structured interviews focused on students' experiences, perceived challenges, and engagement in game-based and simulation-supported learning environments. Classroom observations were conducted as non-participant observations during scheduled lessons, with detailed field notes capturing real-time interactions, instructional practices, and student engagement. In addition, reflective feedback forms were used to gather students' perspectives on their learning processes and experiences.

The integration of multiple data sources enabled triangulation across quantitative and qualitative findings, enhancing the credibility and trustworthiness of the study. Data were collected throughout the intervention period, allowing the study to capture learning as a dynamic and evolving process rather than a static outcome.

Table 2
Data collection overview

Data Source	Participants	Number (n)	Purpose
Achievement Test	Students	64	Measure academic performance
TPACK Scale	Students	64	Assess technological pedagogical knowledge
Engagement Scale	Students	64	Measure behavioral, emotional, cognitive engagement
Semi-structured Interviews	Selected students	10	Explore learning experiences and perceptions
Classroom Observations	Learning sessions	6 weeks	Analyze interaction and instructional practices
Reflection Forms	Experimental group	32	Capture student feedback and reflections

Procedure

The instructional intervention was conducted over a 6-week period and designed to provide a structured yet flexible learning environment integrating game-based and simulation-supported activities. The procedure was implemented during regularly scheduled social studies lessons and aligned with the existing curriculum. The implementation process was structured on a weekly basis.

In Week 1, students were introduced to the digital learning environment and participated in orientation activities designed to familiarize them with the tools, platforms, and instructional

expectations. These activities aimed to ensure that all participants developed a basic level of digital readiness before engaging in the intervention.

During Weeks 2–3, students engaged in game-based learning activities involving interactive tasks, quizzes, and scenario-based challenges. In Weeks 4–5, simulation-supported learning activities were implemented, allowing students to explore real-world scenarios, make decisions, and examine the consequences of those decisions within authentic learning contexts.

The instructional process was carried out during regular class hours (40 minutes per lesson). Various digital platforms were used, including game-based tools (e.g., Kahoot) and web-based simulation environments designed to support student engagement, exploration, and collaborative learning. Throughout the intervention, students participated in structured learning activities that combined game-based learning and simulation-supported tasks, including scenario-based problem-solving, interactive simulations, and collaborative group work. While students were encouraged to explore, make decisions, and reflect on their learning processes, the teacher provided guidance, scaffolding, and feedback when necessary. The instructional design aimed to balance student autonomy with structured support to enhance engagement and conceptual understanding.

Classroom observations were conducted throughout the intervention to monitor student participation, interaction, and engagement. This process allowed the researchers to document students' responses to the learning environment and to capture changes in classroom dynamics over time.

In the final week (Week 6), post-test assessments were administered to both the experimental and control groups. In addition, qualitative data were collected through student interviews and reflective feedback forms to capture students' experiences and perceptions of the learning environment.

The control group followed a traditional instructional approach throughout the intervention period, consisting of teacher-centered instruction, textbook-based activities, and individual exercises. This enabled a comparative examination of the effects of game-based and simulation-supported learning on students' academic achievement and engagement.

Data Analysis

Quantitative and qualitative data were analyzed using complementary approaches to provide a comprehensive understanding of the effects of game-based and simulation-supported learning environments. Quantitative data were analyzed using statistical techniques to examine differences between the experimental and control groups. Descriptive statistics were calculated to summarize students' performance and engagement levels, while inferential analyses, including independent samples t-tests and analysis of covariance (ANCOVA), were conducted to determine the significance of differences between groups while controlling for pre-test scores. These analyses enabled the evaluation of the effectiveness of the instructional intervention in terms of academic achievement, engagement, and technological pedagogical competencies.

Prior to inferential analyses, the assumptions of normality, homogeneity of variance, and linearity were examined. Normality was assessed through skewness and kurtosis values, which fell within acceptable ranges. Homogeneity of variance was evaluated using Levene's test, and the assumptions required for ANCOVA were checked before conducting the analyses. The results indicated that the data met the necessary assumptions for parametric statistical procedures.

Qualitative data were analyzed using reflexive thematic analysis, following the approach outlined by Braun and Clarke (2006, 2021). The analysis was conducted in two stages. In the

first stage, an inductive approach was used to identify patterns and themes emerging from the data. Interview transcripts, observation notes, and reflective feedback were systematically coded to capture students' experiences, interactions, and perceptions of the learning environment. Initial codes were generated from recurring patterns in the data and subsequently organized into broader categories and themes. To enhance trustworthiness, coding decisions and theme development processes were documented throughout the analysis process, creating an audit trail. Representative excerpts from interviews and reflection forms were used to support thematic interpretation. In the second stage, a deductive approach was employed to interpret the identified themes in relation to the TPACK framework. This process enabled the study to connect empirical findings with theoretical constructs and to examine how game-based and simulation-supported learning environments reshape technological, pedagogical, and content knowledge.

The integration of quantitative and qualitative findings enabled a triangulated analysis, enhancing the validity and depth of the study. While quantitative data provided measurable evidence of learning outcomes, qualitative data offered insights into the processes underlying these outcomes. This integrative approach supported the development of the proposed TPACK-GSL model, allowing the study to explain not only whether the intervention was effective but also how and why learning occurred within game-based and simulation-supported environments.

Research Ethics

This study was conducted in accordance with the ethical principles governing research involving human participants. Ethical considerations were observed throughout all stages of the research process. Participation in the study was voluntary, and informed consent was obtained from all participants and their parents/legal guardians before data collection. Participants were informed about the purpose of the research, confidentiality procedures, and their right to withdraw from the study at any stage without any negative consequences. All data were anonymized and used solely for scientific and academic purposes.

Findings

The findings of this study are presented across three interrelated themes, integrating quantitative and qualitative data to provide a comprehensive understanding of the impact of game-based and simulation-supported learning environments. The first theme focuses on students' academic achievement and engagement based on quantitative findings. The second theme explores students' experiences and perceptions through qualitative data. The third theme synthesizes these findings to examine their implications for extending existing interpretations of the TPACK framework.

Theme 1: Impact on Academic Achievement and Engagement

Students' academic achievement and engagement were examined through quantitative data collected from pre-test and post-test measures. The results indicated a notable improvement in the experimental group compared to the control group. While both groups demonstrated similar performance levels in the pre-test, the post-test results revealed that students who participated in game-based and simulation-supported learning activities achieved substantially higher scores.

Student engagement also increased in the experimental group. These learning environments appeared to enhance students' behavioral, emotional, and cognitive involvement in the learning process. In contrast, the control group, which followed traditional instructional methods, showed limited change in both achievement and engagement levels.

Overall, the findings indicate that game-based and simulation-supported learning contributed positively to both academic performance and student engagement, supporting the value of learner-centered instructional approaches in social studies education.

Table 3
Pre-test and post-test comparison of academic achievement scores

Group	n	Pre-test M (SD)	Post-test M (SD)	Gain (Δ)	t	p	Cohen's d
Experimental	32	62.40 (8.15)	81.70 (7.20)	+19.30	5.82	< .001	1.45
Control	32	61.80 (7.95)	68.20 (8.05)	+6.40	1.94	.056	0.34

As shown in Table 3, both groups demonstrated similar pre-test scores; however, the experimental group showed a substantially greater increase in post-test scores compared to the control group. The improvement observed in the experimental group was statistically significant ($t = 5.82$, $p < .001$), whereas the change in the control group was not statistically significant ($p > .05$). These findings indicate that the game-based and simulation-supported intervention had a significant positive effect on students' academic achievement. Effect size analysis further revealed a large effect for the experimental group and a small-to-moderate effect for the control group.

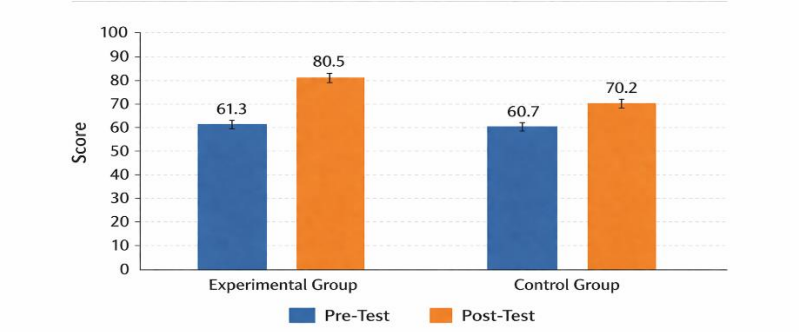


Figure 3
Comparison of pre-test and post-test scores

Theme 2: Student Experiences in Game-Based and Simulation-Supported Learning

Students' experiences in game-based and simulation-supported learning environments were explored through qualitative data obtained from interviews, classroom observations, and reflective feedback. The findings revealed that these environments enhanced students' motivation and involvement in the learning process.

Many students reported that game-based and simulation-supported activities made learning more enjoyable than traditional instruction. The use of scenarios, challenges, and digital tasks encouraged students to take a more active role in learning and engage more deeply with the content. As one student noted, "The activities were more interesting because we were not just listening, we were doing things ourselves." This reflects a shift from passive reception to active involvement in learning.

Students also emphasized the importance of collaboration in supporting their learning experiences. Group-based tasks and problem-solving activities encouraged communication, idea sharing, and collective decision-making. For instance, one student stated, "Working with my friends helped me understand better because we discussed what to do together." These findings suggest that collaborative learning contributed positively to students' understanding of course content.

However, some challenges were also identified. A number of students reported difficulties in adapting to new digital tools and expressed the need for clearer guidance during certain activities. As one student explained, "Sometimes it was confusing when we didn't know what to

do next." This finding highlights the importance of structured support and scaffolding when implementing technology-supported learning environments.

Overall, the findings suggest that game-based and simulation-supported learning environments can support meaningful learning experiences when accompanied by appropriate guidance and instructional support.

Theme 3: Toward a Conceptual Extension of TPACK through Game-Based and Simulation-Supported Learning

The integration of quantitative and qualitative findings suggests that game-based and simulation-supported learning environments may provide useful insights for extending existing interpretations of the TPACK framework. Rather than representing technology integration solely as a static combination of technological, pedagogical, and content knowledge, the findings indicate that these domains may interact in more fluid ways within technology-rich learning environments.

The results show that students engaged more actively with content when technological tools were embedded within carefully designed learning activities. In these contexts, technology functioned not merely as a supporting tool but as an integral component of the learning process, shaping how knowledge was constructed and applied.

Furthermore, the findings highlight the importance of pedagogical design in mediating the relationship between technology and content. Game-based and simulation-supported activities required careful structuring, guidance, and scaffolding, emphasizing that effective technology integration depends not only on access to digital tools but also on how these tools are implemented within instructional settings.

More specifically, the findings suggest that technology integration in game-based and simulation-supported environments may be influenced not only by the interaction between technological, pedagogical, and content knowledge, but also by learner participation, feedback exchange, and collaborative meaning-making processes. In this respect, the proposed TPACK-GSL model offers an initial conceptual extension of TPACK by drawing attention to factors that may influence how technological and pedagogical knowledge are enacted in practice.

Based on these findings, the study proposes the TPACK-GSL model as a preliminary conceptual framework for understanding technology integration in game-based and simulation-supported learning environments. The model offers a conceptual perspective that may contribute to future discussions and empirical investigations concerning technology integration in educational settings.

Discussion

The findings of this study provide important insights into the role of game-based and simulation-supported learning in enhancing students' academic achievement, engagement, and technological pedagogical competencies. Consistent with previous research, the results indicate that interactive and experiential learning environments can improve student outcomes when effectively integrated into instructional practices (Fitrianto & Saif, 2024; Makransky & Petersen, 2021). Beyond confirming existing findings, the study contributes to the literature by exploring how these learning environments may inform broader understandings of the relationships among technology, pedagogy, and content knowledge.

Unlike traditional interpretations of TPACK that primarily emphasize the integration of teacher knowledge domains, the findings suggest that technology integration may also be influenced by learner interaction, participatory engagement, and context-responsive pedagogical

processes. From this perspective, the proposed TPACK-GSL model highlights how feedback, collaboration, and experiential participation may shape technology-supported learning environments and offers a preliminary conceptual extension to ongoing discussions of dynamic TPACK models.

In line with prior studies on game-based and simulation-supported learning, the results indicate that these approaches promote active engagement and deeper learning (Radianti et al., 2020; Sheffield et al., 2024). Students in the experimental group not only achieved higher academic performance but also demonstrated increased behavioral, emotional, and cognitive engagement. These findings support the argument that learning is more effective when students are actively involved in meaningful and interactive tasks rather than passive instructional settings (Fawns, 2022).

The effectiveness of the intervention appears to be associated with three interrelated mechanisms: immediate feedback provided by digital environments, increased student interaction, and collaborative problem-solving opportunities (Dede et al., 2018; Fawns, 2022). Social studies is particularly suitable for such environments because it involves decision-making, interpretation of real-world scenarios, and perspective-taking, all of which can be supported through game-based and simulation-supported learning (Dede et al., 2018; Squire, 2013). The findings further suggest that technology may function not merely as a supporting tool but as an important component shaping participation, interaction, and meaning-making processes within learning environments (Fawns, 2022; Scherer et al., 2019).

At the same time, the qualitative findings highlight that the effectiveness of these environments depends on pedagogical design and instructional support. Similar to findings reported in previous research, students' experiences are shaped not only by the availability of digital tools but also by the level of guidance, scaffolding, and feedback provided by the teacher (Martín-Rodríguez & Madrigal-Cerezo, 2025). This reinforces the idea that technology alone does not transform learning; rather, meaningful change emerges through the interaction of learners, teachers, and contextual conditions (Fawns, 2022).

A key contribution of this study lies in providing initial empirical and conceptual insights that may inform future extensions of the TPACK framework. While TPACK has traditionally been conceptualized as a structured combination of knowledge domains (Koehler & Mishra, 2009), the findings suggest the value of considering more dynamic and context-dependent interpretations. Recent studies emphasize that technology integration may be understood as an evolving process shaped by interaction, context, and pedagogical practice (Angeli & Valanides, 2014; Scherer et al., 2019). Consistent with this perspective, the findings indicate that game-based and simulation-supported learning environments may offer useful insights into how technological, pedagogical, and content knowledge interact within technology-rich learning contexts.

Furthermore, the results indicate that student decision-making, collaboration, and engagement play an important role in shaping learning processes. This aligns with constructivist perspectives, which conceptualize learning as an active, participatory, and socially mediated process (Dede et al., 2018). In this sense, game-based and simulation-supported environments can be viewed as interactive ecosystems that support knowledge construction and application.

Based on these findings, this study proposes the TPACK-GSL model as a preliminary conceptual framework that highlights experiential, interactive, and context-responsive dimensions of learning. Rather than representing a fully developed reconceptualization of TPACK, the model offers an initial conceptual perspective that may contribute to ongoing discussions and future empirical investigations concerning technology integration in education.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, the duration of the intervention was limited to six weeks, which may not have been sufficient to capture long-term learning outcomes and sustained changes in students' engagement and technological pedagogical competencies. Second, the study was conducted within a single educational context and involved a relatively small sample of secondary school students, which may limit the generalizability of the findings to other educational settings and learner populations.

A further limitation concerns the theoretical implications of the study. The proposed TPACK-GSL model should be regarded as a preliminary conceptual framework derived primarily from students' learning outcomes, experiences, and perceptions within game-based and simulation-supported learning environments. Because the study did not directly examine teachers' enactment of TPACK in classroom practice, caution is warranted when making broader claims regarding the reconceptualization of the TPACK framework.

In addition, the proposed model has not yet been validated across different disciplines, age groups, educational levels, or instructional settings such as online, blended, and face-to-face learning environments. Future research should therefore examine the applicability and robustness of the TPACK-GSL model in diverse educational contexts and through studies that directly investigate teachers' technology integration practices.

Despite these limitations, the findings provide valuable empirical and conceptual insights into the potential role of game-based and simulation-supported learning in shaping technology-supported educational experiences. Further research is needed to refine, validate, and extend the proposed model across a broader range of contexts.

Conclusion and Implications

This study examined the impact of game-based and simulation-supported learning environments on students' academic achievement, engagement, and technological pedagogical competencies. The findings demonstrate that integrating interactive and experiential learning approaches into social studies education can significantly enhance both learning outcomes and student engagement. In particular, students who participated in game-based and simulation-supported activities showed higher levels of academic performance and engagement compared to those in traditional learning environments.

Beyond these empirical findings, this study contributes to the literature by offering a preliminary conceptual extension of the TPACK framework. The results suggest that technology integration may be understood not only as the intersection of technological, pedagogical, and content knowledge, but also as a process shaped by interaction, participation, and pedagogical design within technology-rich learning environments. The proposed TPACK-GSL model provides an initial conceptual perspective for considering how experiential and interactive dimensions of learning may inform future interpretations of technology integration.

More specifically, this study contributes to ongoing discussions on dynamic TPACK models by suggesting that technology integration may involve learner participation, interaction, feedback, and experiential engagement alongside traditional knowledge domains. However, the proposed TPACK-GSL model should be regarded as a preliminary conceptual framework derived from students' learning outcomes and experiences. Further research is needed to

examine and validate the model across different educational contexts, disciplines, age groups, and instructional settings.

The findings also have important practical implications. For educators, the study highlights the need to design learning environments that balance technological tools with effective pedagogical strategies, including scaffolding, feedback, and structured guidance. Simply integrating digital tools is insufficient; meaningful learning emerges when technology is embedded within well-designed instructional practices. For policymakers and curriculum designers, the results emphasize the importance of supporting digital pedagogy through professional development, infrastructure, and flexible learning environments that encourage innovation and experimentation.

Furthermore, this study suggests that game-based and simulation-supported learning environments can play a critical role in developing 21st-century skills, such as critical thinking, collaboration, and decision-making. These skills are increasingly important in contemporary educational contexts and should be considered in the design of future curricula and instructional approaches.

In conclusion, this study provides empirical evidence and initial conceptual insights into the role of game-based and simulation-supported learning in technology-supported education. By examining these approaches through the lens of TPACK, the study offers a preliminary conceptual framework that may inform future research on technology integration and digital pedagogy. Future studies should continue to test, refine, and validate the proposed TPACK-GSL model across a broader range of educational contexts and learner populations.

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