

Digital Games Can Enhance K-12 Students' 21st-century skills: A Systematic Review**Abstract**

The rapidly evolving landscape of the 21st century demands learners equipped with so-called 21st-century skills such as creativity, communication, collaboration, and critical thinking. Digital games have emerged as powerful learning tools, but their effectiveness depends on how they are designed to foster these skills. In this systematic review, following the PRISMA guidelines, we analyzed 68 studies to address several research questions aimed at understanding how well-designed digital games can enhance 21st-century skills. The findings suggest that games incorporating problem-solving mechanics, real-time feedback, adaptive challenges, and collaborative tasks are most effective in fostering skill development. Most studies reported positive impacts of digital games on students' 21st-century skills. These studies underscore the importance of engagement-driven, interactive, and experiential learning environments. Furthermore, constructionist theory informed many of these game designs by emphasizing active knowledge construction through hands-on exploration. This review highlights that the success of digital games in education is not merely tied to genre but rather to thoughtful design choices, such as scaffolding, autonomy-supporting mechanics, and meaningful problem contexts. By analyzing the principles of effective game design, this systematic review provides practical insights for educators, researchers, and developers aiming to create digital games that enhance 21st-century skills.

Keywords: digital games, 21st-century skills, systematic review, creativity, problem-solving, critical thinking, collaboration, communication

1. Introduction

In the rapidly evolving job market of the 21st century, the demand for essential skills has been emphasized by swift technological advancements and global shifts (Petersen, 2021). For instance, new developments in artificial intelligence (AI) present both opportunities and challenges (Chiu et al., 2023). As AI increasingly takes over routine cognitive tasks, the demand for human workers performing basic skills is expected to diminish (Bowles & Kruger, 2023). This shift necessitates an emphasis on skills that AI cannot easily replicate—such as critical thinking, creativity, communication, and collaboration—commonly referred to as “21st-century skills.” Consequently, educational systems must evolve to ensure that students develop these competencies and equip them to navigate an ever-changing landscape (Wicks & Paulus, 2022; P21, 2019; Bonfield et al., 2020).

The term “21st-century skills” has gained popularity in recent years, with advocates promoting the prioritization and emphasis of skills such as critical thinking, collaboration, creativity, and digital literacy to prepare students for today’s demands (Thornhill-Miller et al., 2023; Saavedra & Opfer, 2012). Proponents argue that economic and technological changes make targeting these skills more essential in education than ever before (P21, 2019; Voogt & Roblin, 2012). However, the term has also faced criticism in educational circles, with some arguing that these skills are not new and warning that the phrase risks becoming an oversimplified slogan rather than a meaningful integration of knowledge and skills (Lucas, 2019). In this study, we adopt the Partnership for 21st-century skills framework definition of “21st-century skills,” acknowledging the valid concerns about the terminology while agreeing with the advocates on the importance of emphasizing these skills in education.

The 21st-century skills emphasize knowledge, skills, attitudes, and behaviors that are necessary in today's ever-changing landscape (Dede, 2010; Voogt & Roblin, 2012; P21, 2019). Effectively assessing and fostering these skills in students remains an ongoing challenge (Dede, 2010; Voogt & Roblin, 2012; Chen, 2021). K-12 schools play an important role in societal development and in preparing students for an unpredictable future, particularly in light of the emergence of new digital technologies anticipated in the next decade (Reis-Andersson, 2023; Becker, 2023). Many educational systems around the world do not effectively integrate the assessment and development of 21st-century skills into their curriculum (Saavedra & Opfer, 2012), instead, their focus is on standardized testing and rote knowledge acquisition (Chan & Yuen, 2014). This disconnect necessitates innovative strategies to seamlessly assess and foster these pivotal skills within educational systems (Squire, 2005). Digital games are increasingly recognized as powerful learning tools with the potential to assess and cultivate 21st-century skills, and other knowledge, skills, and abilities (Shute & Ke, 2012; Qian & Clark, 2016). Next, we discuss the affordances of digital games as promising vehicles for assessing and fostering 21st-century skills in K-12 education.

1.1 Digital Games: Promising Vehicles for Assessing and Fostering 21st-century Skills

Digital games (aka, video games or computer games) are interactive computer programs played for entertainment on electronic devices (Hamari & Keronen, 2017). These games use real-time simulation, visualization, and interactivity to create engaging gameplay experiences (Boyle et al., 2012). Over the past decades, playing digital games has become highly popular for children and adults alike (Rideout et al., 2010; Adipat et al., 2021; Wang et al., 2022). Numerous reports highlight the growing interest in digital games among K-12 students, with over 3.38 billion gamers worldwide (Ofcom, 2023; Global Games Market Report, 2023). Consequently, using digital games for learning presents a valuable opportunity for educators. Digital games offer unique affordances such as interactivity, immersion,

immediate feedback, and personalization, which can enhance the learning experience (Gee, 2005; Plass et al., 2015; Rigby & Ryan, 2011; Tamborini & Bowman, 2010; Shute, 2011; Squire, 2011). Moreover, these games motivate players through various elements, including fantasy, challenge, curiosity, control, cooperation, competition, and recognition (Malone & Lepper, 1987).

However, excessive or inappropriate gaming has been linked to negative effects such as aggression, addiction, and poor academic performance (Anderson & Bushman, 2001; Petry et al., 2014; Gentile et al., 2004). To mitigate these adverse effects, strategies such as parental monitoring, promoting a balanced lifestyle, and fostering critical thinking skills are recommended (Gentile et al., 2004; LeBlanc et al., 2013; Klimmt, 2009). Despite these concerns, many researchers have been studying the impact of digital games on students' 21st-century skills (Ke, 2009; Yu et al., 2021; Winaldo & Oktaviani, 2022). For instance, several meta-analyses have found positive effects of digital games on knowledge acquisition, motivation, and academic achievement, indicating their promise for improving learners' educational outcomes (Ke, 2009; De Freitas, 2018; Gui et al., 2023; Sun et al., 2023; Dahalan et al., 2023; Adipat & Wongwanich, 2019). Nevertheless, it is important to note that not all digital games have a positive effect on learners' educational outcomes (Shute & Ke, 2012); well-designed games that leverage their unique affordances while focusing on learning objectives can significantly enhance learners' knowledge, skills, attitudes, and engagement (Barab et al., 2010; Gee, 2005; Shute & Ke, 2012). We discuss these affordances in more depth next.

1.2 Well-designed Digital Games

The effectiveness of digital games on learning depends on how well the game design elements align with established learning theories and the characteristics of effective learning (Vogel et al., 2006; Qian & Clark, 2016). Well-designed digital games incorporate learning

principles, such as active learning, immediate feedback, and scaffolding to support the acquisition and application of knowledge and skills (Boyle et al., 2016). These games provide learners with opportunities to engage in meaningful problem-solving activities, experiment with different strategies, and receive adaptive feedback (Shute & Ke, 2012). By aligning game mechanics with learning objectives, game designers can create intrinsically motivating experiences for learners that promote deep learning and transfer of skills to real-world contexts (Gee, 2005).

However, poorly designed digital games that lack clear learning goals, provide insufficient guidance may fail to engage learners or result in unintended outcomes (Kafai & Burke, 2015). Such games may prioritize entertainment over learning which lead to a disconnection between the gaming experience and the educational objectives (Sweller et al., 2011). Therefore, educators and game designers must collaborate to develop high-quality digital games that integrate learning theories and game design elements to maximize the effects of those games on supporting 21st-century skills (Hirumi et al., 2010).

1.3 Theories behind Well-designed Digital Games

When designing digital games for learning and fostering 21st-century skills, it is important to consider various learning, motivational, and psychological theories (Plass et al., 2015). Learning theories help instructors to understand how students learn using digital games (Gee, 2005; Yong et al., 2020). Behaviorist theories focus on observable behaviors and the environmental stimuli that shape those behaviors through conditioning. Behaviorist principles are frequently applied in digital game design through features such as rewards, points, leaderboards, badges, clear goals, and consistent feedback (Linehan et al., 2011). Cognitivist theories focus on the mental processes behind behaviors (Ertmer & Newby, 1993; Schunk, 2012). Cognitive theories influence digital game design by stressing the importance of appropriately structured content, manageable chunks of information, activation of prior

knowledge, and strategies to gain and maintain attention (Plass et al., 2015). Constructivist learning theory views learning as an active, constructive process where learners create their own subjective representations of objective reality. Digital games align well with constructivist ideas by situating learning in meaningful contexts and providing opportunities for discovery and problem-solving (Yong et al., 2020). Motivational and psychological theories play a critical role in understanding player engagement and learning in digital games. For instance, Self-Determination Theory (SDT; Ryan & Deci, 2000) emphasizes the importance of autonomy, competence, and relatedness in fostering intrinsic motivation, which can be applied to game design to create more engaging experiences. Flow theory (Csikszentmihalyi, 1990) describes an optimal state of immersion and focus, often achieved in well-designed games that balance challenge and skill. The ARCS motivational model (Keller, 1987) focuses on four key elements—Attention, Relevance, Confidence, and Satisfaction—which can be integrated into game mechanics to enhance player motivation and learning outcomes. These theories are frequently used in educational game design to create engaging and effective learning experiences (Boyle et al., 2016; Plass et al., 2015). Digital games align well with these theories and models and create immersive and engaging learning environments for the learners (Plass et al., 2015).

By integrating insights from diverse learning, motivational, and psychological theories into digital game design, game-based learning researchers, educators, and game developers can create effective learning environments that cater to the needs and preferences of diverse learners (Plass et al., 2015). In the current systematic review, we analyzed the included studies based on the learning theories emphasized or explicitly used by the researchers in the design of the digital games. Specifically, we coded the included studies in this systematic review based on *behaviorist, cognitivist, constructivist, and motivational and psychological* theories.

1.4 Games Design Elements of Well-designed Digital Games

Well-designed digital games incorporate a variety of game design elements that contribute to their effectiveness in promoting learning and the development of 21st-century skills (Dondlinger, 2007; All et al., 2016; Ahmad, 2019). Although there is no consistent or comprehensive categorization of digital game design elements across the literature, Plass et al. (2015) propose the following game design elements as essential: game *mechanics*, *visual aesthetics*, *narrative*, *incentives*, *musical score*, *learning objectives with related content and skills*, and *social interaction design*.

Digital *game mechanics* represent the gameplay activities repeated throughout the game, the rules, procedures, and interactions that define how a game operates and how players engage with it (Plass & Homer, 2012; Plass et al., 2013). *Visual aesthetics*, such as graphics, animations, and user interface design, can enhance player engagement and motivation (Mayer, 2014). *Narrative* elements, including characters, plot, and dialogue, can provide context and meaning to the learning content, enhancing retention and transfer of knowledge (Dickey, 2015). *Incentives*, such as points, badges, and leaderboards, can motivate players and provide feedback on their progress (Plass et al., 2015). The *musical score* provides background sounds to direct player attention, induce emotions, and acknowledge events. *Learning objectives* and related content and skills define the subject matter covered by the game, influencing the design of other elements (Plass & Homer, 2012). *Social interaction* design involves elements such as collaboration, competition, and social feedback, which can foster a sense of community, promote the exchange of ideas, and enhance motivation.

In this systematic review, we coded the digital game design elements that were particularly highlighted and emphasized in the included studies by focusing on their effectiveness in promoting learning and the development of 21st-century skills. By analyzing

these findings, we identified the most impactful and well-supported game design elements that contribute to meaningful skill development. This review translates these insights into actionable design principles and offers practical recommendations for educators and game developers seeking to create digital games that effectively enhance 21st-century skills. Next, we discuss various digital game genres.

1.5 Digital Game Genres

When selecting games to build any skills, it is essential to consider digital game genres as each game genre has the potential to develop certain skills more effectively than others. Some common digital game genres include action games, adventure games, role-playing games (RPGs), strategy games, simulation games, and educational games. Researchers have proposed various classifications for digital game genres based on design, mechanics, narrative, and aesthetics (Lee et al., 2015; Clarke et al., 2017).

In this study, in light of the various game genre categorizations in the literature, we coded the included studies using the following genres: action, role-playing, strategy, simulation, sandbox, adventure, serious, board games, multiplayer, and puzzle. Action games focus on physical challenges and reaction speeds, requiring players to have quick reflexes and hand-eye coordination, as seen in games such as *Call of Duty* (Apperley, 2006). Similarly, role-playing games (RPGs) emphasize story, exploration, and character advancement, with players assuming roles of characters in fictional settings, exemplified by *The Witcher 3: Wild Hunt* (Lee et al., 2015). In contrast, strategy games prioritize decision-making, planning, and resource management, challenging players to think critically and plan ahead to achieve victory, such as in *Civilization VI*. Simulation games recreate real-world activities, providing players with realistic experiences in various contexts such as driving, flying, or managing, demonstrated by *The Sims* (ESA, 2019). On the other hand, sandbox games offer open-ended gameplay and exploration, allowing players to create and manipulate the game world at their

own pace, with *Minecraft* being a prime example (Clarke et al., 2017). Moreover, adventure games focus on storytelling and puzzle-solving, requiring players to explore and interact with the game environment to progress, as seen in *The Legend of Zelda: Breath of the Wild* (Clarke et al., 2017). Additionally, serious games use gaming for education and training, designed to teach or train players in specific areas while still being engaging, exemplified by *Foldit*. Furthermore, digital board games adapt traditional board game formats to digital platforms, maintaining core mechanics while leveraging digital advantages, such as *Catan* (Lee et al., 2015). Massively multiplayer online (MMO) games allow large numbers of players to interact in persistent worlds, involving social interaction, collaboration, and competition, as demonstrated by *World of Warcraft* (Apperley, 2006). Finally, puzzle games challenge logical thinking and pattern recognition, requiring players to solve puzzles to progress, exemplified by *Tetris* (ESA, 2019).

In this systematic review, we explore how different digital game genres have been employed to foster 21st-century skills in K-12 education. By examining the relationship between game genres and specific skills, we aim to gain insights into the most effective game genres for supporting 21st-century skills. This knowledge can inform the design and selection of digital games for educational purposes and guide future research efforts in game-based learning.

1.6 Rationale for the Current Systematic Review

Multiple systematic reviews and meta-analyses have focused on the impact of digital games on enhancing basic knowledge acquisition in subjects such as physics and mathematics (Bulger et al., 2021; Yudintseva, 2021; Riopel et al., 2019; Hussein et al., 2019; Hainey et al., 2016). For instance, Yang and Chang (2020) reviewed 28 studies and suggested that open-ended, sandbox-style games that encourage exploration and allow for user-generated content can promote divergent thinking and creative problem-solving among

students. Similarly, Barzilai and Blau (2014) reviewed 22 studies and highlighted that digital games requiring interdependent tasks, clear communication, and shared goals can effectively support the development of collaboration skills among students. Moreover, Wouters et al. (2013) conducted a review focusing on the use of digital games for acquiring basic knowledge and skills, rather than 21st-century skills, and found significant educational benefits. Additionally, Clark et al. (2016) analyzed the impact of digital games on science education, emphasizing that game-based learning environments can improve conceptual understanding and engagement in scientific topics. Another study by Boyle et al. (2016) reviewed the role of digital games in fostering motivation and engagement in learning, identifying key design elements that enhance educational outcomes. However, to the best of our knowledge, there are no comprehensive systematic reviews that have synthesized the recent research (from 2014 until now) on using digital games to enhance the broad range of 21st-century skills in K-12 settings.

As we mentioned, there is comparatively limited research on the effects of digital games on developing 21st-century skills. In a systematic review, Qian and Clark (2016) included 137 studies, 29 of which examined 21st-century skills. The results of this review provided preliminary evidence that digital games can promote these skills. Specifically, Qian and Clark's analysis of studies from 2010 to 2014 showed that digital games, grounded in learning theories, can improve skills such as critical thinking. The authors noted that while these results indicate the potential of thoughtfully designed digital games to enhance 21st-century skills, further research is needed, particularly in areas such as creativity, collaboration, and communication.

Given the rapid proliferation of research on digital games and 21st-century skills since 2014 (see Fig. 1), there is an opportunity to revisit and update the systematic review conducted by Qian and Clark (2016). An updated systematic review can provide a current

understanding of how digital games are being used to target and impact 21st-century skills.

This review addresses the gap by examining recent research to uncover the essential game design principles that effectively foster 21st-century skills. Rather than merely summarizing past studies, we establish a conceptual framework that highlights practical strategies for integrating digital games into education. By identifying key design elements, theoretical foundations, and pedagogical considerations, this review offers actionable guidance for educators, researchers, and game developers aiming to create impactful learning experiences.

In this systematic review, we address the following research questions:

- 1) What are the trends in research on digital games for 21st-century skills from 2014 to 2023?
 - a) Who are the target audiences of the included studies?
 - b) What are the 21st-century skills that were targeted in the included studies?
 - c) What subject matters were used in digital games to target 21st-century skills?
- 2) What are the effects of digital games on K-12 students' 21st-century skills?
 - a) What research design and methodological considerations were found in the included studies?
 - b) What durations were allocated to gameplay in the included studies?
- 3) How have the included digital games been designed to target and possibly enhance K-12 students' 21st-century skills?
 - a) What learning theories have informed the studies' game design?
 - b) What digital game genres have been used for each 21st century skill?
 - c) What digital game design elements have been incorporated for each 21st century skill?

Examining these research questions yields insights into leveraging digital games as engaging tools for advancing 21st-century skills. By identifying effective digital games

genres, game design elements, and theories, this review empowers researchers and educators to harness the potential of digital games to create engaging, student-centered learning experiences that can promote 21st-century skills (Plass et al., 2015).

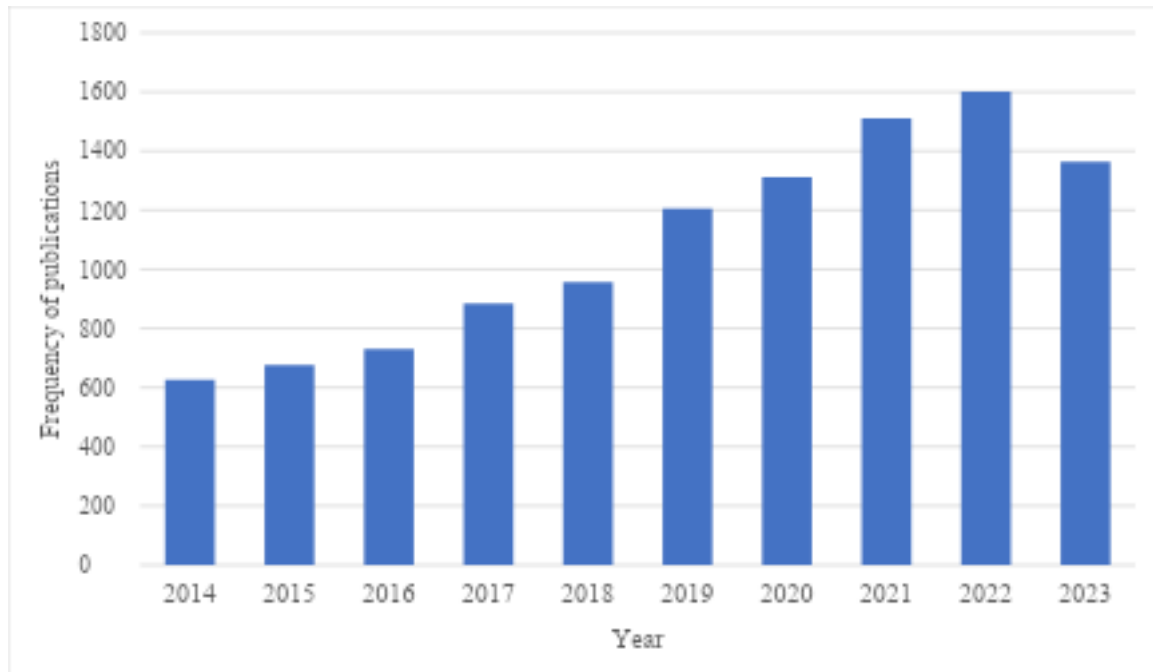


Fig. 1. Growth in Research on Digital Games and 21st-century skills Exported from Web of Science.

Moreover, this review advances digital game-based learning research by highlighting gaps in the existing literature and providing recommendations for future studies. The current review also holds implications for digital game designers and developers seeking to create digital games that effectively promote 21st-century skills. By identifying the digital game design elements and mechanics that have been shown as effective, this review provides a framework for designing digital games that are for improving students' 21st-century skills (Plass et al., 2015). Next, we discuss the method we used to find, analyze, and synthesize the findings of the studies we included in this systematic review.

2. Method

We followed PRISMA guidelines (Moher et al., 2009) to conduct this systematic review, synthesizing findings on digital games enhancing 21st-century skills in K-12 settings. Inclusion criteria were studies published between 2014-2023, in English, examining digital games' impact on 21st-century skills in K-12. This update follows Qian and Clark (2016), covering 2010-2014. We included both peer-reviewed and non-peer-reviewed studies to avoid publication bias. Exclusion criteria were pre-2014 publications, non-English studies, and those focused solely on students with disabilities. We specifically analyzed digital games' impacts on students' 21st-century skills (see Table 1).

Table 1

Inclusion and exclusion criteria.

Criteria	Inclusion Criteria	Exclusion Criteria
Date	• 2014-2023 (inclusive)	• Out of the date range
Language	• English	• Non-English
Relevance	• Digital games • At least one of 21st-century skills outcome variable • Examine the effects of digital games on the 21st-century skills	• Non digital games • Non 21st-century skills outcome variable • If there are other purposes than examining the effects of digital games on 21st-century skills (e.g., assessment, creating statistical models)
Target Audience	• K-12	• Higher education • Adult learning • Learners with special need and/or disabilities
Manuscript Type and Research Design	• Peer-reviewed • Non-peer reviewed • Observational studies • Experimental • Quasi-experimental • Correlational studies	• Reviews • General correlational studies (i.e., studies that do not involve playing specific digital game)

We searched databases including Eric, Web of Science, Science Direct, ProQuest, Google Scholar, and Scopus, adapting search strategies for each platform. For example, in Web of Science, we used: (game OR “online game” OR “video game” OR “digital game” OR “computer-based game” OR “game-based learning”) AND (learning OR education OR “elementary school” OR student OR “k-12 education” OR “secondary education”) AND

(“21st-century skills” OR “problem-solving” OR “critical thinking” OR collaboration OR creativity OR communication OR “information skills”). See Appendix A for search strings. Our initial search yielded 3068 studies. Using Covidence, two researchers independently screened abstracts and full texts, resolving discrepancies through multiple rounds. This process resulted in 69 studies for quality assessment, including 14 hand-searched studies.

2.1 Quality Assessment

To assess study quality, we used the Critical Appraisal Skills Programme (CASP) checklist (Singh, 2013). This checklist evaluates research aspects such as aims, methodology, and data collection. For qualitative studies, we assessed clear aims, methodology, recruitment, data collection, researcher-participant relationship, ethics, data analysis, and findings. Quantitative and mixed methods studies were evaluated using an adapted CASP checklist with additional criteria from Pluye et al. (2009). These criteria included research aims, methodology, recruitment, sampling, measurement, confounding variables, findings, and generalizability, along with mixed methods justification, data integration, and reliability.

Studies were rated as high (over 70% “yes”), medium (40-70% “yes”), or low (under 40% “yes”) quality, based on Pluye et al. (2009). To prevent bias, a second researcher independently assessed the studies. After resolving conflicts, only 1 study was rated low and excluded, leaving 68 studies for review (see Fig. 2). The research team conducted a thorough content analysis of each paper. After independent data extraction, researchers discussed and resolved disagreements to reach full consensus. Variables extracted included title, digital game name, targeted skill, game design elements, learning theory, game genre, country, educational level, audience, and sample size. The results of our systematic review are presented in the section 3.

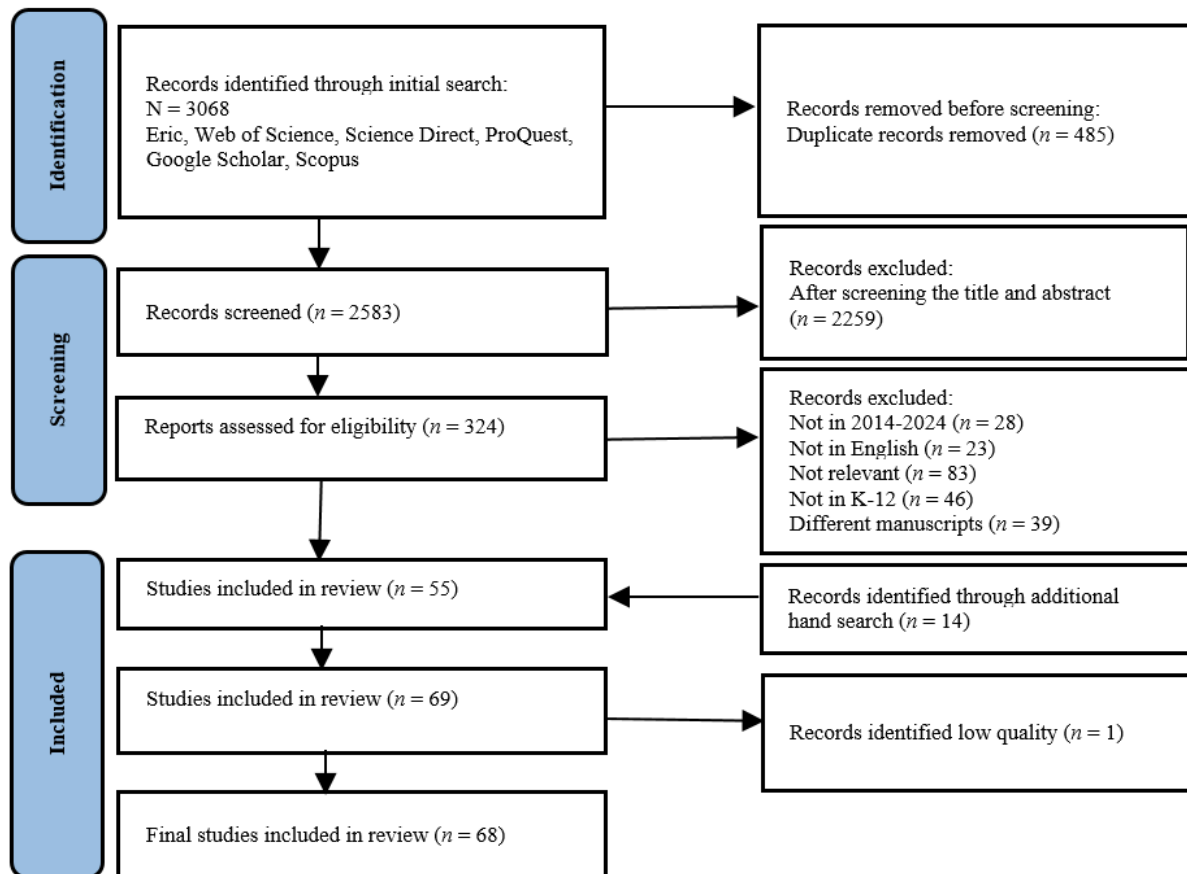


Fig. 2. PRISMA Flow Diagram Detailing the Steps in the Identification and Screening of Sources.

3. Results

3.1 RQ1: Key Trends in Use of Digital Games and 21st-century Skills

Our review of the 68 studies (see Table 2) on digital games and the 21st-century skills included participants from the first grade to high school. The studies represented a range of educational levels, including 29 studies (31.0 %) with elementary school students, 17 studies (19.5 %) with middle school students, and 43 studies with secondary school students (49.4 %). The total sample size across the 68 studies ranged from 6 to 528 participants with a total sample size of 5977 across all studies.

Table 2

Studies that used digital games to improve 21st-century skills.

First Author, Year	Country	Game	Duration	Ed. Level	<i>n</i>	Skill(s)	Quality
Contreras-Espinosa, 2022	Mexico	Various Games	3 days	S	90	4C	89%
Morgan, 2015	USA	Minecraft	9 months	E & S	10	4C	100%
Haya, 2020	Indonesia	Gasik 2.0	NA	8th G	75	4C	75%
Ali, 2021	Malaysia	Forest Multiplication	NA	5th G	29	P, Cr, & Ct	60%
Lawlor, 2017	Ireland	Brain Game	4 months	S	144	P, Col, Com, & Ct	78%
Chu, 2020	USA	Globaloria	1 academic year	M & S	NA	Col	70%
Duncan, 2020	USA	Breakout EDU	9 weeks (5 hours)	3rd G	76	Col	90%
Bressler, 2019	USA	School Scene Investigators	5 class periods	M	12	P, Col, Com, & CT	89%
Song, 2019a	USA	Seaball	10 days (3 sessions)	7th & 8th G	104	CT	50%
Ke, 2019	USA	E-Rebuild	6 weeks	M	61	P	80%
Santria, 2019	Indonesia	Ladder Snake	3 hours and 20 minutes	8th G	29	Col & Com	62%
Wen, 2018	Singapore	ARC	5 months	E	49	Col	75%
Scholten, 2017	Netherlands	Minecraft	8 sessions	S	NA	Col & Com	67%
Smith, 2014	USA	QA/ARX	5 days	4th G	15	P, Col, Com, & Ct	100%
Ruipérez-Valiente, 2020	USA	Shadowspect	2 days	S	150	Col	75%
López-Faican, 2020	Ecuador	EmoFindAR	1 session	E	38	Com	90%
Atwood-Blaine, 2019	USA	ARIS	6 days in 2 months	E & M	37	Cr	90%
Vidergor, 2021	Israel	Digital Escape Room	1 session	E	528	Col	75%
Yang, 2015	Taiwan	NATycoon City	27 weeks	S	68	P, Cr, & CT	87%
Hussein, 2019	Malaysia	Ecoship Endeavour	6 sessions	5th G	127	CT	87%
Yeh, 2019	Taiwan	DGLC-B	6 weeks	5th & 6th G	83	Cr	75%
Polyak, 2017	USA	Circuit Runner	30 minutes	M	159	P	87%
Wardani, 2017	Indonesia	AI Chemist Knight	2 months	S	30	CT	75%
Liang, 2021	Taiwan	ARG	1 day	E	44	P & CT	75%
Hsu, 2021	Taiwan	Bio Detective	70 minutes	7th G	128	P	80%

First Author, Year	Country	Game	Duration	Ed. Level	<i>n</i>	Skill(s)	Quality
Gök, 2021	Turkey	Race with Numbers	75 minutes	M	6	P	100%
Chen, 2021	Taiwan	Ren'py	9 weeks	S	46	CT	70%
Sarıçam, 2021	Turkey	Minecraft	4 weeks	6th G	25	Cr	80%
Tsai, 2020	Taiwan	Science Detective Squad	3 weeks	9th G	50	P	87%
Ellison, 2020	UK	Minecraft	60 minutes	E	14	Cr	90%
Danby, 2018	Australia, Norway, and Sweden	Momio	NA	PreK	NA	Col	100%
Checa-Romero, 2018	Spain	Minecraft	8 weeks	S	85	Cr	75%
Davis, 2018	USA	Minecraft	1 hour	M	10	Col	100%
Sung, 2018b	Taiwan	REG	3 weeks	6th G	166	P	87%
Tobar-Muñoz, 2017	Colombia	AR Ole Cierraosjos	2 weeks	E	51	P, Col, & Com	100%
Gürbüz, 2017	Turkey	Weather Forecast Game	NA	E	45	P	75%
Hsiao, 2014	Taiwan	ToES Game	4 weeks	5th G	51	Cr	87%
Eseryel, 2014	USA	McLarin's Adventures	1 year	9th G	88	P	75%
Kahila, 2020	Finland	Various Digital Games	NA	6th G 9th G	41	P, Cr & Col	100%
Osman, 2020	Malaysia	MyKimDG Module	8 weeks	S	138	Com	87%
Chen, 2021	Taiwan	NA	4 days	S	32	CT	70%
Rugoero, 2017	UK	Project Tech	6 months	S	35	P	75%
Chen, 2021c	Taiwan	Element Enterprise Tycoon	8 sessions	S	48	P	70%
Hwang, 2014	Taiwan	Sustainable Home	10 weeks	E	167	P	100%
Kao, 2017	Taiwan	Crayon Physics Deluxe	2 months	S	126	P & Cr	87%
Barzilai, 2014	Israel	Shakshouka Restaurant	1 session	E	182	P & CT	75%
Chou, 2021	Taiwan	Void Broken: The Qing Dynasty	1 session	S	70	P	87%
Hughes-Roberts, 2020	UK	Pocket code	8 weeks	E	37	Col	100%

First Author, Year	Country	Game	Duration	Ed. Level	<i>n</i>	Skill(s)	Quality
Ke, 2020	USA	E-Rebuild	7 sessions	M	56	P	90%
Liang, 2023	Taiwan	MCCG	2 stages (2 hours)	S	55	Col	87%
Sung, 2018	Taiwan	NA	2 sessions (100 minutes)	6th G	53	P	87%
Sun, 2018	Taiwan	Professor Sudoku	1 session (40 minutes)	6th G	126	P	87%
Turchi, 2019	UK	TAPASPlay	15 minutes	S	18	P	80%
Lin, 2020	Taiwan	TUI	80 minutes	P	7	P	90%
Yeh, 2020	Taiwan	DGLC-SD-A	90 minutes	3rd & 4th G	82	Cr	75%
Martin-SanJose, 2015	Spain	NA	5 class periods	E	100	Col	100%
van der Meij, 2020	Netherlands	Energities	1 class period	E	32	Com & Col	87%
Checa-Romero, 2016	Spain	Harry Potter and the Goblet of Fire	2 months	E	13	CT	89%
Tzortzoglou, 2023	Greece	EcoAegean	3 phases	E	NA	P, Com, Col, CT	100%
Samin, 2022	Indonesia	Critical Thinking Adventure	NA	S	65	CT	87%
Qibtiyah, 2023	Indonesia	NA	NA	S	27	CT	89%
Liu, 2022	USA	Zoombinis	1 hour	E	30	P	75%
Assapun, 2023	Thailand	Control Wave, PW Mastery	4 sessions	S	90	P	100%
Kuo, 2023	Taiwan	SDBG	12 weeks	S	76	Cr	87%
Efendi, 2023	Indonesia	NA	NA	S	58	CT	87%
Poiroux, 2016	Norway	Minecraft	37 minutes	E	NA	Col	62%
Hall, 2021	USA	Fortnite	2 hours	E	15	CT	78%
Buffum, 2015	USA	ENGAGE	8 weeks	M	48	Col	89%

Note. EL = Educational Level; G= Grade; E = Elementary; M = Middle school, S = Secondary; 4C=Creativity, Communication, Collaboration, and Critical Thinking; Cr = Creativity; Col=Collaboration; Com = Communication; CT = Critical Thinking; P = Problem-solving; NA = Not Applicable; Ed. = Educational; MCCG = mandatory contribution-based collaborative gaming approach; DGLC-SD-A = Digital Game-based Learning for Creativity with Self-Determination, level A; Weeks, months, and years indicate that these studies did not provide the exact time

In terms of the targeted skills, problem-solving was the most frequently addressed skill ($n = 22$) followed by collaboration ($n = 21$), critical thinking ($n = 21$), creativity ($n = 14$), and communication ($n = 11$). A subset of 4 studies focused specifically on all four 21st-century skills: creativity, communication, collaboration, and critical thinking. In terms of educational level, collaboration ($n = 17$) and critical thinking ($n = 13$) were the most targeted skills for elementary school students. For the middle school, high school, and secondary school students, problem-solving was the most commonly targeted skill, with 13, 29, and 8 studies focused in this area respectively. Furthermore, we identified the central content or topics around which these digital games were designed and implemented within the diverse contexts of academic research such as STEM, language, business, history, computational thinking, and other areas (e.g., informal education and not applicable) with STEM studies accounting for the highest proportion at 27 studies (see Fig. 3). The not applicable category includes studies that did not focus on a specific academic subject but instead examined the general impact of digital games on skills development.

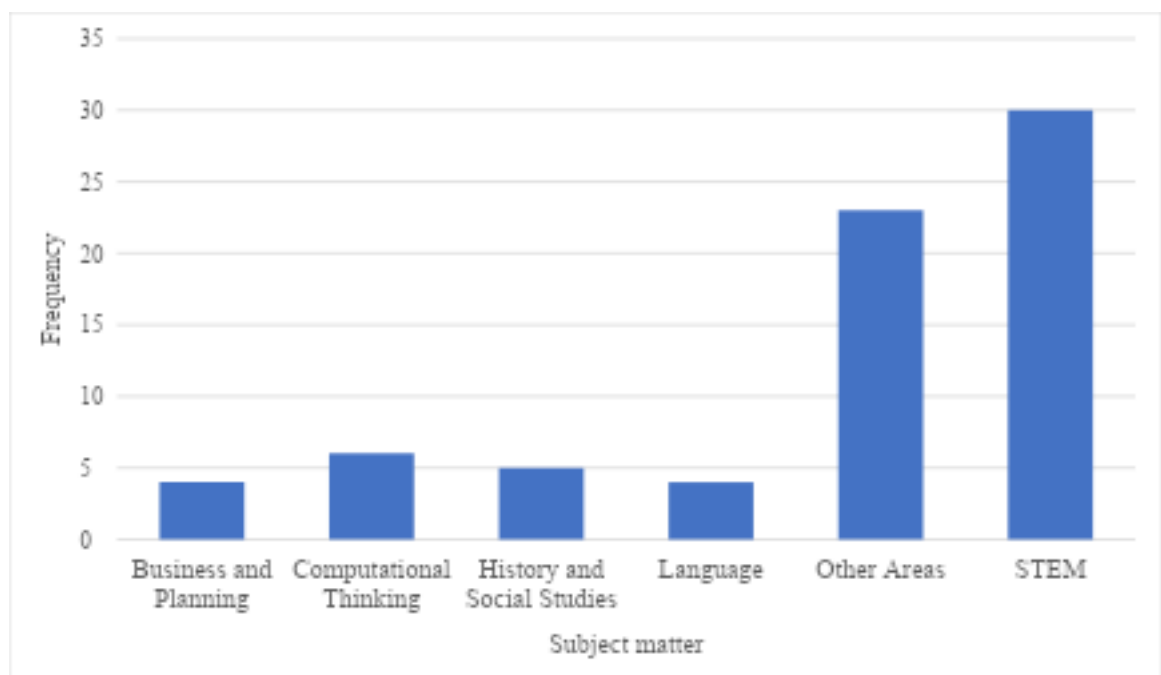


Fig. 3. Subject Area Distribution of Included Studies ($n = 68$).

3.2 RQ2: Digital Games' Effects on K-12 Students' 21st-century Skills

3.2.1 Digital Games' Effects on Problem-solving

All studies ($n = 22$) related to problem-solving showed positive effects, improving dimensions such as solution-finding, problem representation, reasoning, proving, and transferring knowledge (Sun et al., 2018; Turchi et al., 2019; Liu & Israel, 2022). Positive effects were linked to game features such as playful and collaborative learning experiences (Turchi et al., 2019), promoting problem-solving attributes (Ruggiero & Green, 2017), engaging students in planned processes (Ke, 2019), and creating peer learning opportunities (Danby et al., 2018).

Research designs varied, with quasi-experimental designs ($n = 7$), case studies ($n = 6$), mixed-methods ($n = 5$), design-based research ($n = 2$), action research ($n = 1$), and computational psychometrics ($n = 1$). Gameplay duration ranged from single sessions of 15 minutes (Turchi et al., 2019) to 120 minutes (Sung & Hwang, 2017), to interventions spanning weeks or even a year. Some studies had multiple sessions, such as four 45-minute sessions (Ali et al., 2021) or six 40-minute sessions (Kao et al., 2017). Others had extended periods without exact times, such as 4 weeks (Yang, 2015) and 6 weeks (Sung et al., 2018). Duration can impact results; for instance, Kao et al. (2017) found longer interventions led to higher problem-solving performance.

Shorter durations also showed positive results. Sung et al. (2018) found a 6-week intervention enhanced deep-strategy behaviors and learning in science inquiry. Ali et al. (2021) reported improvements in multiplication skills after four 45-minute sessions. The effectiveness of digital games depends on factors such as game design, implementation, and alignment with learning objectives (Wouters & van Oostendorp, 2017). Duration should be considered along with these factors to determine overall effectiveness. Next, we discuss digital games' effects on creativity.

3.2.2 Digital Games' Effects on Creativity

Out of 14 studies related to creativity, 13 showed positive effects of digital games on K-12 students' creativity. Games such as *ToES* (Hsiao et al., 2014), *DGLC-SD-A* (Yeh et al., 2020), *SdBG* (Kuo et al., 2023), and *Minecraft* (Ellison & Drew, 2020; Sariçam & Yıldırım, 2021) enhanced creativity through active participation, problem-solving, collaboration, and imagination. These games improved facets of creative thinking, including fluency, flexibility, originality, and elaboration (Kuo et al., 2023; Sariçam & Yıldırım, 2021). Digital games also helped students visualize ideas (Ellison & Drew, 2020), boosted creative self-efficacy and mastery (Yeh et al., 2019), and generated flow experiences (Hsiao et al., 2014; Yeh et al., 2020). However, Morgan (2015) did not explicitly show positive effects.

Research designs varied: quasi-experimental ($n = 5$), mixed-methods ($n = 5$), one-group pretest-posttest ($n = 2$), and action research ($n = 2$). Despite methodological diversity, all studies reported positive impacts, indicating robust benefits of game-based learning for creativity. Gameplay duration ranged from a single 60-minute session to a full semester. Short-term and long-term studies both yielded positive results. Checa-Romero and Gómez (2018) found that a single 40-minute *Minecraft* session stimulated creative thinking and problem-solving. Kao et al. (2017) observed creativity improvements after two 50-minute sessions with a physics-based game. Longer interventions also showed significant benefits: Yeh et al. (2020) noted enhanced creativity after a 15-week program, and Hsiao et al. (2014) reported improvements after a 10-week intervention. Next, we focus on collaboration.

3.2.3 Digital Games' Effects on Collaboration

The majority of studies ($n = 20$) out of 21 on collaboration demonstrated positive effects of digital games on K-12 students' collaboration skills. Games such as *Minecraft* (Scholten et al., 2017), *Breakout EDU* (Duncan, 2020), and *School Scene Investigators*

(Bressler et al., 2019) enhanced teamwork and communication abilities. These games improved joint problem-solving, shared decision-making, and effective communication (Bressler et al., 2019; Martín-SanJosé et al., 2015). For example, *Gasik 2.0* improved students' 21st-century skills, including collaboration, through team-based gameplay (Haya et al., 2020). Digital games also developed a sense of shared purpose (Fonseca et al., 2020), coordination (Wen, 2018), and collaborative learning experiences (Vidergor, 2021).

Research designs varied: quasi-experimental ($n = 7$), mixed-methods ($n = 6$), case studies ($n = 5$), and design-based research ($n = 3$). Despite methodological diversity, most studies reported positive impacts on collaboration, showing consistent benefits across approaches. Mixed-methods and case studies included qualitative data collection, providing insights into collaborative processes (Duncan, 2020; Fonseca et al., 2020). For example, Lawlor and Tangney (2016) used a case study to examine the Brain Game's effectiveness in developing collaboration through authentic learning activities. Gameplay duration ranged from a single 60-minute session (Vidergor, 2021) to several months (Scholten et al., 2017). Both short-term and long-term studies yielded positive results. Vidergor (2021) found that a single digital escape room session stimulated collaborative problem-solving. Bressler et al. (2019) observed improved collaborative scientific practices after a brief augmented reality game intervention. Longer interventions also showed significant benefits. Scholten et al. (2017) reported enhanced collaborative urban planning skills after a semester-long *Geocraft* program, while Wen (2018) noted improved collaborative language learning following an eight-week augmented reality game intervention. Next, we discuss the effects of digital games on communication skills.

3.2.4 Digital Games' Effects on Communication

The majority of studies ($n = 9$) out of 11 on communication showed positive effects of digital games on K-12 students' communication skills. Games such as a *collaborative*

augmented reality game (Bressler et al., 2019), *scripted serious game* (van der Meij et al., 2020), *Brain Game* (Lawlor & Tangney, 2016), and *Minecraft* (Partridge, 2022) fostered communication through collaborative discourse, peer interaction, and idea articulation. These games improved communal language use, dialogue quality, and effectiveness in professional simulations. Digital games enhanced students' scientific discourse (Bressler et al., 2019), quality of predictions, deliberations, and strategy discussions (van der Meij et al., 2020), and communication in problem-solving scenarios (Lawlor & Tangney, 2016). Two studies reported mixed or non-significant results (Partridge, 2022; Smith, 2014).

Research designs varied: quasi-experimental ($n = 4$), qualitative methods ($n = 3$), mixed-methods ($n = 3$), and case study ($n = 1$). Despite methodological diversity, most studies reported positive impacts, showing robust benefits of game-based learning for communication skills. Gameplay duration ranged from single 90-minute sessions to year-long interventions, with other durations including 1-3 sessions ($n = 6$) and 4-8 weeks ($n = 4$). Both short-term and long-term studies yielded positive results. For example, van der Meij et al. (2020) found that a single 90-minute session of a scripted serious game stimulated higher-quality dialogues. López-Faican and Jaen (2020) observed improvements after four 45-minute sessions with a mobile augmented reality game. Longer interventions also showed significant benefits: Partridge (2022) reported enhancements after a 6-week *Minecraft* implementation, and Smith (2014) noted improvements after a year-long virtual environment integration.

These findings suggest digital games effectively foster communication skills in both short-term and long-term applications. The versatility of digital games as educational tools is evident, promoting communication skills through brief activities or sustained curricular integrations. Next, we discuss the effects of digital games on critical thinking.

3.2.5 Digital Games' Effects on Critical Thinking

The majority of studies (20 out of 21) on critical thinking showed positive effects of digital games on K-12 students' critical thinking skills. Games such as *Ecoship Endeavour* (Hussein et al., 2019), *Al Chemist Knight* (Wardani et al., 2017), and *Seaball—Semester at Sea* (Song & Sparks, 2019) fostered problem-solving, decision-making, and analytical skills. These games improved facets of critical thinking, including analysis, evaluation, interpretation, and argumentation (Chen & Chuang, 2021; Chen & Wu, 2021). Additionally, digital games enhanced students' practical knowledge application (Lawlor & Tangney, 2016), higher-order thinking skills (Yang, 2015), and inquiry-based learning (Liang et al., 2021).

Research designs varied: quasi-experimental ($n = 7$), case studies ($n = 6$), mixed-methods ($n = 4$), design-based research ($n = 2$), action research ($n = 1$), and computational psychometrics ($n = 1$). Despite methodological diversity, most studies reported positive impacts, indicating robust benefits of game-based learning for critical thinking. Gameplay duration varied from single 15-minute sessions (e.g., Turchi et al., 2019) to year-long interventions (e.g., Eseryel et al., 2014). Short-term interventions (1-3 sessions) were common ($n = 6$), such as the 90-minute period in van der Meij et al.'s (2020) study. Medium-term interventions (4-8 weeks) included Yang's (2015) 4-week and Sung et al.'s (2018) 6-week studies. Longer interventions included a 12-week study by Hwang et al. (2014) and a semester-long implementation by Chen & Chuang (2021). Both short-term and long-term studies yielded positive results, highlighting the potential of digital games to enhance critical thinking across various time frames. For example, Checa-Romero and Gómez (2018) found that a single 40-minute *Minecraft* session enhanced critical thinking and problem-solving. Yang's (2015) 4-week study reported substantial improvements in higher-order thinking skills and academic achievement. These findings suggest digital games effectively foster critical thinking in both short-term lessons and long-term curricular implementations.

Our analysis reveals that digital games have significant positive effects on various 21st-century skills among K-12 students. We now shift our focus to RQ3, which explores the design of digital games for enhancing 21st-century skills.

3.3 RQ3: Digital Games' Design for 21st-century Skills

In this section, we examine how the digital games included in this review were *designed* to target 21st-century skills. We analyze the included studies through the lenses of relevant theories, digital game genres, and digital game design elements.

To illustrate the distribution of the studies regarding the skills, theories, and game genres, we created a three-layer graph (Fig. 4). The graph shown is divided into 3 layers: (1) 21st-century skills: including problem-solving, creativity, collaboration, communication, and critical thinking which indicates a balanced distribution among the skills; (2) theories: including behaviorist, cognitivist, constructionist, and motivational and psychological theories, and (3) digital game genres: including adventure, simulation, sandbox, strategy, puzzle, and role-playing games.

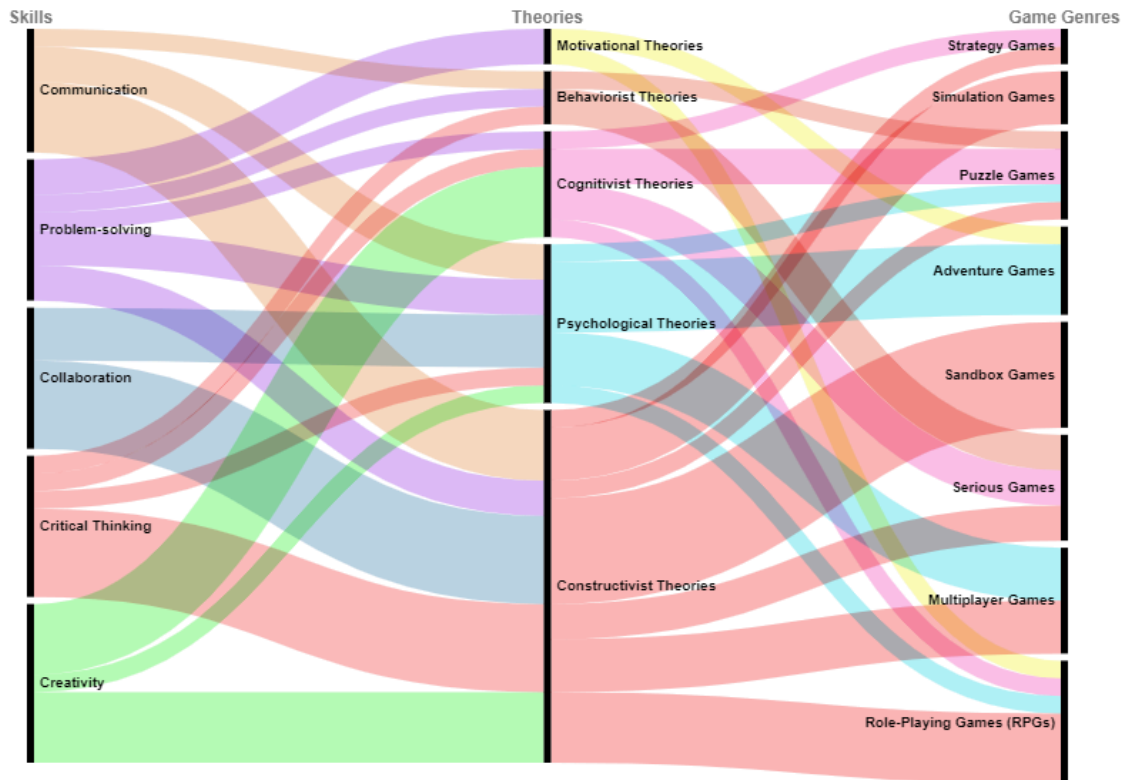


Fig. 4. The Distribution of the Studies in Terms of Targeted Skills, Theories, and Game Genres.

In the following, we explore theories that research indicates effectively cultivate 21st-century skills. Grounding these genres, we highlight prevalent digital game genres and game design elements on how digital games can enhance 21st-century skills. By understanding the interconnections between theories, game genres, and design elements, educators and game designers can create more effective digital games that foster 21st-century skills among K-12 students.

3.3.1 Digital Games Design for Problem-solving

Out of 68 reviewed studies, 22 used digital games to foster problem-solving. Theories included constructivist ($n = 8$), experiential learning ($n = 4$), situated learning ($n = 3$), and self-determination ($n = 2$). Constructivist theory emphasized active knowledge construction, as seen in E-Rebuild (Ke, 2019) and Quest Atlantis (Smith, 2014). Experiential learning

involved concrete experiences and reflection, exemplified by *McLarin's Adventures* (Eseryel et al., 2014). Situated learning placed students in authentic roles, as in *Urban Science* (Bagley & Shaffer, 2015) and *EcoAegean* (Tzortzoglou et al., 2023). Self-determination theory informed motivational elements in *Circuit Runner* (Polyak et al., 2017) and *Professor Sudoku* (Sun et al., 2018).

Common game genres for problem-solving included puzzle games ($n = 5$), simulations ($n = 4$), adventure games ($n = 4$), multiplayer games ($n = 3$), and role-playing games ($n = 3$). Puzzle games such as *Professor Sudoku* (Sun et al., 2018) and *Crayon Physics* (Kao et al., 2017) required critical thinking and strategic planning. Simulations, such as *Virtual CEOs* (Yang, 2015), provided realistic problem-solving environments. Adventure games such as *Science Detective Squad* (Tsai & Hsu, 2020) and *Alien Rescue* (Liu et al., 2014) used narratives to contextualize problems. Multiplayer games, such as *TAPASPlay* (Turchi et al., 2019), required collaboration. Role-playing games such as *Urban Science* (Bagley & Shaffer, 2015) engaged students in authentic problem-solving.

Key design elements for problem-solving included challenging tasks ($n = 5$), scaffolding ($n = 4$), interactive environments ($n = 8$), collaboration ($n = 7$), feedback mechanisms ($n = 7$), narrative ($n = 6$), and open-ended exploration ($n = 6$). For example, *Crayon Physics Deluxe* (Kao et al., 2017) used adaptive hints, and *Crystal Island* (Lester et al., 2014) offered graduated feedback. Interactive environments in *Quest Atlantis* (Smith, 2014) and *River City* (Lester et al., 2014) facilitated experimentation. Collaborative elements in *GIGAME* (Sanchez & Olivares, 2011) fostered teamwork. Feedback in *Alien Rescue* (Liu et al., 2014) guided problem-solving. Narratives in *Science Detective Squad* (Tsai & Hsu, 2020) and *E-Rebuild* (Ke, 2019) increased engagement. Open-ended exploration in *Minecraft* (Tangkui & Keong, 2023) encouraged creative problem-solving. In the section 3.3.2, we will discuss the design aspects of digital games to enhance creativity.

3.3.2 Digital Games Design for Creativity

Out of the 68 reviewed studies, 14 focused on using digital games to enhance creativity. This section discusses the learning theories, game genres, and design elements used to foster creativity.

The most prevalent theories were constructivist ($n = 4$) and self-determination theory (SDT) ($n = 2$). Other theories included experiential learning ($n = 1$), cognitive-affective interaction ($n = 1$), flow theory ($n = 2$), mindful learning ($n = 1$), and Vygotsky's sociocultural theory ($n = 1$). Constructivist theory emphasized active learning through exploration, as seen in *Minecraft* (Ellison & Drew, 2020). Experiential learning involved learning through experiences, exemplified by *Minecraft* Education Edition (Saricam & Yildirim, 2021). SDT highlighted autonomy, competence, and relatedness, fostering intrinsic motivation in story-based games (Yeh et al., 2020).

Game genres included sandbox ($n = 4$), educational ($n = 3$), puzzle ($n = 2$), story-based ($n = 1$), digital board games ($n = 3$), role-playing games ($n = 1$), and simulation games ($n = 1$). Sandbox games such as *Minecraft* allowed for open-ended exploration and creative expression (Ellison & Drew, 2020). Puzzle games, such as *Crayon Physics Deluxe*, challenged players to think critically and solve problems creatively (Kao et al., 2017). Story-based games provided immersive narratives stimulating imaginative thinking (Yeh et al., 2020).

Key game design elements enhancing creativity included open-ended exploration ($n = 6$), challenging tasks and scaffolding ($n = 4$), collaboration and peer feedback ($n = 3$), interactive environments ($n = 2$), and narrative storytelling ($n = 2$). Open-ended exploration encouraged experimentation and creative expression, as seen in *Minecraft* studies (Ellison & Drew, 2020). Challenging tasks with scaffolding maintained engagement and fostered creative thinking (Kao et al., 2017). Collaborative elements and peer feedback promoted idea

exchange and creativity (Yeh et al., 2020). This section reviewed the theories, game genres, and design elements used in digital games to enhance creativity. In the section 3.3.3 we will discuss the use of digital games to enhance collaboration.

3.3.3 *Digital Games Design for Collaboration*

Out of 68 studies, 22 focused on using digital games to enhance collaboration. This section explains the learning theories, game genres, and design elements that enhance collaboration.

The most frequently used theories were constructivist ($n = 9$), sociocultural ($n = 5$), situated learning ($n = 3$), self-determination ($n = 2$), and flow theory ($n = 1$). Constructivist and social constructivist theories emphasized active learning and social interaction (Martín-SanJosé et al., 2015; Bressler et al., 2019). For example, Martín-SanJosé et al. (2015) used historical simulations, while van der Meij et al. (2020) highlighted scripted collaboration. Other theories emphasized social interaction, cultural context, intrinsic motivation, and engagement (Fonseca et al., 2020; Wen, 2018).

The most common game genres were educational games ($n = 9$), location-based/augmented reality games ($n = 5$), sandbox games ($n = 5$), puzzle ($n = 2$), and escape room games ($n = 1$). Educational games often incorporated collaborative elements (Martín-SanJosé et al., 2015). For example, *Energities* (van der Meij et al., 2020) promoted interaction and decision-making. Location-based games blended real-world and virtual experiences, encouraging collaboration (Fonseca et al., 2020). Sandbox games allowed for creativity and problem-solving (Bressler et al., 2019), while puzzle and escape room games required communication and teamwork (Hava et al., 2020).

Key design elements enhancing collaboration included team-based challenges ($n = 12$), role assignment ($n = 8$), communication tools ($n = 8$), interactive environments ($n = 6$), narrative/storytelling ($n = 4$), feedback/reflection ($n = 4$), points/rewards systems ($n = 2$), and

time constraints ($n = 2$). Team-based challenges required players to work together (Martín-SanJosé et al., 2015). Role assignment encouraged interdependence (van der Meij et al., 2020), and communication tools facilitated information sharing (Fonseca et al., 2020). Other elements, such as interactive environments and narrative, promoted engagement and problem-solving (Wen, 2018). By integrating these theories, genres, and design elements, the studies demonstrated digital games' potential to enhance collaboration skills in K-12 education. This section reviewed studies on using digital games to enhance collaboration. In the section 3.3.4 we will discuss designing digital games to enhance communication.

3.3.4 Digital Games Design for Communication

Out of 68 studies, 11 focused on using digital games to improve communication skills among K-12 students. This section discusses the learning theories, game genres, and design elements that enhance communication.

The most prevalent theories were constructivism ($n = 6$), experiential learning ($n = 4$), social learning ($n = 3$), situated learning ($n = 2$), and flow theory ($n = 2$). Constructivism underpinned games such as *Minecraft*, *Geocraft*, and *EcoAegean*, emphasizing hands-on experiences and social interactions (Morgan, 2015; Scholten et al., 2017; Tzortzoglou et al., 2023). Experiential learning was evident in games such as *School Scene Investigators*, engaging students in real-world problem-solving (Smith, 2014). Social learning theory informed games such as *EmoFindAR*, focusing on emotional intelligence and peer interactions (López-Faican & Jaen, 2020). Situated learning was applied in location-based games (e.g., *EcoAegean*) which requires contextual communication and collaboration (Tzortzoglou et al., 2023).

The most frequently used game genres were sandbox games ($n = 4$), augmented reality ($n = 3$), simulation ($n = 2$), role-playing ($n = 2$), and educational card games ($n = 1$). Sandbox games such as *Minecraft* foster communication through collaborative building tasks

(Morgan, 2015; Scholten et al., 2017; Partridge, 2022). Augmented reality games, such as *EcoAegean* and *EmoFindAR*, encourage real-world communication and teamwork (Tzortzoglou et al., 2023; López-Faican & Jaen, 2020). Simulation games such as *Energities* provide realistic scenarios for practicing communication (van der Meij et al., 2020). Role-playing games such as *School Scene Investigators* promote empathy and diverse perspectives (Smith, 2014).

Key design elements enhancing communication included collaborative tasks ($n = 7$), role-playing and perspective-taking ($n = 5$), open-ended exploration ($n = 4$), real-time feedback ($n = 3$), and in-game communication tools ($n = 3$). Collaborative tasks, such as those in *Geocraft*, required students to discuss and negotiate urban planning (Scholten et al., 2017). Role-playing elements in *Energities* stimulated argumentation and discussion (van der Meij et al., 2020). Open-ended exploration in *Minecraft* allowed for creative interaction (Partridge, 2022). Real-time feedback in *EmoFindAR* encouraged immediate adaptation (López-Faican & Jaen, 2020). In-game communication tools in *Minecraft* facilitated ongoing dialogue (Morgan, 2015). This section explored studies on designing digital games to enhance communication skills. Next, we will examine how digital games are designed to foster critical thinking, including the theories, genres, and design elements involved.

3.3.5 Digital Games Design for Critical Thinking

Out of 68 studies, 22 focused on using digital games to improve critical thinking among K-12 students. These studies explored game design, implementation, and evaluation aimed at enhancing higher-order thinking skills. This section discusses the learning theories, game genres, and design elements that target critical thinking.

The most cited theories were constructivist ($n = 8$), problem-based learning ($n = 5$), experiential learning ($n = 4$), and situated learning ($n = 3$). Constructivist theory emphasized active knowledge construction and social interaction, as seen in games such as *Ecoship*

Endeavour (Hussein et al., 2019) and a digital role-playing game by Chen and Wu (2021). Problem-based learning was used in games such as *Virtual CEOs* (Yang, 2015), involving story-like tasks in a business simulation. Experiential learning informed games such as *Minecraft* (Morgan, 2015), promoting learning through experience and reflection. Situated learning was applied in games such as *Quest Atlantis/Atlantis Remixed* (Smith, 2014) and *EcoAegean* (Tzortzoglou et al., 2023), where students solved real-world problems in authentic contexts. These theories emphasize active engagement, real-world problem-solving, and contextualized learning to develop critical thinking skills.

The most common game genres were simulation ($n = 6$), educational ($n = 5$), role-playing ($n = 4$), augmented reality ($n = 3$), and puzzle games ($n = 2$). Simulation games such as *Virtual CEOs* provided realistic business environments for applying critical thinking skills. Educational games such as *Forest Multiplication* (Ali et al., 2021) taught academic content while promoting critical thinking. Role-playing games such as *School Scene Investigators* (Bressler et al., 2019) encouraged students to assume different roles, fostering critical analysis. Augmented reality games such as *EcoAegean* blended real-world and digital environments for immersive learning (Tzortzoglou et al., 2023). Puzzle games challenged students to solve complex problems and develop logical reasoning (Wardani et al., 2017). These genres offer unique ways to develop critical thinking through authentic problem-solving and perspective-taking.

Key game design elements included problem-solving tasks ($n = 12$), collaborative learning ($n = 9$), feedback mechanisms ($n = 8$), role-playing ($n = 7$), scaffolding ($n = 6$), and interactive environments ($n = 5$). Problem-solving tasks were central to games such as *Brain Game* (Lawlor & Tangney, 2016). Collaborative learning was emphasized in games such as *Fortnite* (Hall, 2021). Feedback mechanisms provided immediate responses in games such as *Forest Multiplication* (Ali et al., 2021). Role-playing elements were evident in games such as

EcoAegean (Tzortzoglou et al., 2023). Scaffolding was used in games such as *Virtual CEOs* (Yang, 2015), and interactive environments were featured in sandbox games such as *Minecraft* (Morgan, 2015). These elements create engaging and challenging environments that promote critical thinking by encouraging analysis, evaluation, and creative problem-solving.

4. Discussion

This systematic review explored the role of digital games in fostering 21st-century skills from 2014 to 2023. In this review we focused on trends, effects, and digital game design considerations. Through an analysis of 68 selected studies, this review uncovers how digital games have been leveraged to develop problem-solving, creativity, collaboration, communication, and critical thinking. The following sections present key findings for each research question by emphasizing critical insights that inform the design and implementation of effective game-based learning experiences.

4.1 RQ1: Key Trends in Use of Digital Games and 21st-century Skills

Regarding trends in using digital games to foster 21st-century skills (RQ1), this systematic review reveals several notable trends. The prominence of problem-solving may indicate areas for future research and development in game-based learning. This finding suggests that researchers and educators recognize the significance of problem-solving skills in today's rapidly evolving and complex world, where the ability to identify, analyze, and resolve problems is crucial for success in both academic and professional contexts (Qian & Clark, 2016).

The distribution of studies across educational levels indicates a broad interest in game-based learning across K-12 education. This widespread adoption aligns with the growing recognition of digital games as valuable educational tools (Plass et al., 2015).

Our findings align with Qian and Clark's (2016) conclusions regarding the significant role of game design in enhancing 21st-century skills. Both studies underscore the importance of integrating established learning theories into game design, particularly constructivist theories. The emphasis on design-based and educational games as effective tools for skill development is a common thread in both reviews. Additionally, the importance of incorporating multiple game design elements—such as collaboration, narrative, and feedback mechanisms—is highlighted in both studies that reflects a shared understanding of what makes digital games effective.

A noteworthy advancement since Qian and Clark's (2016) study is the more balanced representation of research across different 21st-century skills in our review. While Qian and Clark identified relatively few studies focusing on communication and creativity, our review indicates a growing interest and progress in these areas. This balanced focus is promising, suggesting that the field of digital games are evolving to address a broader range of skills more comprehensively. The increased number of studies exploring communication and creativity reflects an encouraging trend towards a more holistic approach to 21st-century skill development through digital games.

4.2 RQ2: Digital Games' Effects on Students' 21st-century Skills

Our analysis of the studies reveals that well-designed digital games can significantly enhance K-12 students' problem-solving skills. The effectiveness of digital games in improving problem-solving abilities can be attributed to various factors, such as the incorporation of epistemic simulations and collaborative knowledge construction strategies in game design. The diversity in research designs, methodologies, and intervention durations across the studies highlights the robustness of the positive impact of digital games on problem-solving. These findings aligns with previous research highlighting the potential of digital games to enhance problem-solving abilities (Qian & Clark, 2016; Shute & Ke, 2012).

The positive effects on creativity reported in 13 out of 14 studies are promising. Most studies noted significant improvements in creative thinking skills, scientific creativity, flow experience, and creativity facets such as fluency, flexibility, originality, and elaboration. The success of these interventions is attributed to the purposeful design of digital game-based learning programs that incorporate elements encouraging creative thinking and expression. The varied research designs and methodologies further strengthen the validity of these findings. However, a small effect size reported in one study highlights the importance of sustained engagement and longer exposure to realize the full potential of digital games in enhancing creativity. These results support the notion that digital games can provide open-ended environments fostering creative thinking and expression (Hsiao et al., 2014). Sandbox games such as *Minecraft* are particularly effective in promoting creativity, aligning with research on the benefits of open-world games for creative skill development (Cipollone et al., 2014).

The positive effects on collaboration skills reported in 20 out of 22 studies highlight the potential of digital games as platforms for fostering teamwork and social interaction. These findings align with research emphasizing the social aspects of game-based learning (Bluemink et al., 2010). Multiplayer games and collaborative problem-solving tasks are particularly effective in promoting collaboration skills. While some studies show the potential of well-designed digital games to enhance collaborative processes, others highlight challenges related to group dynamics and inequitable learning experiences. The effectiveness of digital games in fostering collaboration appears influenced by factors such as game design, group composition, and implementation strategies. Findings suggest that complex, narrative-driven games with elements such as riddles and time limits may be more effective in promoting collaboration compared to simpler games. The varied research designs and

methodologies highlight the need for further research to identify optimal conditions and strategies for leveraging digital games to support collaboration in educational settings.

While fewer studies focused specifically on communication skills, the majority reported positive effects. These results support the potential of digital games to create contexts that necessitate and enhance communication skills (Barr, 2018). Games requiring player interaction and coordinated efforts, such as *Minecraft* and augmented reality games, are particularly effective in promoting communication skills. The emphasis on in-game communication tools and collaborative tasks underscores the importance of designing games that explicitly require and support communication among players. This aligns with research on structuring game-based learning experiences to promote desired learning outcomes (Ke, 2016). Collaborative games that incorporate interdependent roles, promote discourse around data analysis, and foster productive conversations among players have been shown to improve engaged communication and communal language use. However, the lack of significant effects in a few studies highlights the importance of factors such as intervention duration, collaboration guidance, and individual differences among players. The diverse methodologies employed across the studies further strengthen the validity of these findings.

The positive effects on critical thinking skills reported in 20 out of 22 studies are encouraging. These findings support the potential of digital games to create complex problem spaces that promote higher-order thinking (Kim et al., 2009). Simulation games, role-playing games, and puzzle games are particularly effective in fostering critical thinking skills. The incorporation of problem-solving tasks, feedback mechanisms, and scaffolding in game designs aligns with research on effective instructional design for promoting critical thinking (Halpern, 1998). The positive results across various game genres and implementation durations suggest that critical thinking can be effectively targeted through diverse game-based approaches. Well-designed games that present ill-structured problems and

encourage collaboration have been shown to promote higher levels of critical thinking discourse compared to traditional instruction. However, non-significant findings in one study with limitations related to sample size and COVID-19 restrictions highlight the need for further research with larger, more representative samples and optimal implementation conditions to fully understand the potential of digital games for critical thinking skills development.

4.3 RQ3: Digital Game Design for 21st-century Skills

To address the last question (Q3) the analysis of digital game design considerations in this systematic review provides insights into the learning theories, digital game genres, and design elements that have informed the development of digital games for 21st-century skills. Due to differences among 21st-century skills we discuss each skill separately to provide targeted insights into how digital games can be effectively designed to support their development.

4.3.1 Problem-solving

Learning theories such as constructivist, experiential learning, and situated learning have been prominently featured in studies investigating problem-solving skills in digital games. Constructivist emphasizes the active construction of knowledge through hands-on experiences and reflection, while experiential learning highlights the importance of learning through direct experience and iteration. Situated learning theory stresses the role of authentic contexts and real-world problems in fostering meaningful learning. These theories suggest that effective problem-solving skills are developed when learners are engaged in active, contextually relevant problem-solving experiences within digital game environments.

Among the digital game genres explored for problem-solving, puzzle, simulation, and serious games have emerged as the most commonly used. Puzzle games challenge players to solve increasingly complex problems using logic, pattern recognition, and trial-and-error,

promoting the development of analytical thinking and persistence. Simulation games provide realistic environments where players can apply problem-solving strategies to authentic scenarios, such as managing resources or optimizing systems. Serious games, designed with educational objectives in mind, often present learners with complex, real-world problems that require the application of problem-solving skills in various domains, such as science, engineering, or social issues.

Key game design elements that have been highlighted for promoting problem-solving skills include challenges, feedback, levels, narratives, and collaboration. Challenges provide players with opportunities to test and refine their problem-solving strategies, while immediate feedback allows them to learn from their successes and failures. Progressive levels of difficulty help players develop their skills gradually, maintaining engagement and motivation. Narratives can contextualize problems, making them more meaningful and relatable to players. Finally, collaborative problem-solving in multiplayer settings can foster the development of communication, teamwork, and social problem-solving skills.

The learning theories, game genres, and design elements are interconnected in supporting problem-solving skill development. For example, the puzzle and strategy genres align with constructivist and constructionist theories by presenting problem situations that require active investigation and interpretation by the students, as evidenced in two studies (Gök & İnan, 2021; Gürbüz et al., 2017). Similarly, RPGs and adventure games provide virtual worlds and social features that support collaborative and situated learning theories, enabling players to engage in social problem-solving activities, as demonstrated in three studies (Danby et al., 2018; Eseryel et al., 2014; Sung & Hwang, 2017). Furthermore, the integration of challenges, feedback, and collaboration in these game genres reflects the principles of experiential learning and situated cognition, promoting active engagement and knowledge construction through problem-solving experiences.

4.3.2 Creativity

Studies exploring creativity in digital games have often drawn upon constructivist learning theories, flow theory, and self-determination theory (Hsiao et al., 2014; Yeh et al., 2019). Constructivist theories emphasize the importance of learner-driven exploration, experimentation, and creation in fostering creative thinking (Kafai & Burke, 2015). Flow theory highlights the role of optimal challenge, clear goals, and immediate feedback in promoting a state of deep engagement and creative immersion (Csikszentmihalyi, 1990). Self-determination theory stresses the importance of autonomy, competence, and relatedness in nurturing intrinsic motivation, which is important for creative expression (Ryan & Deci, 2000). These theories suggest that digital games can enhance creativity by providing learners with opportunities for open-ended exploration, self-directed learning, and immersive experiences.

Sandbox games and serious games have been identified as the most promising genres for fostering creativity (Kao et al., 2017; Saricam & Yildirim, 2021). Sandbox games, such as *Minecraft*, provide players with open-ended virtual environments where they can freely create, build, and experiment with various tools and resources (Ellison & Drew, 2020). These games encourage players to use their imagination, take risks, and develop innovative solutions to self-directed challenges. Serious games, on the other hand, can be designed to target specific creative skills, such as divergent thinking, problem-finding, or artistic expression, through carefully crafted challenges and scenarios that encourage players to think outside the box and generate novel ideas (Checa-Romero & Gómez, 2018).

Game design elements that have been highlighted for promoting creativity include open-endedness, customization, feedback, collaboration, and challenges (Kuo et al., 2023; Yang, 2015). Open-ended game environments provide players with the freedom to explore, experiment, and create without strict limitations or predefined goals. Customization options

allow players to personalize their gaming experiences, fostering a sense of ownership and self-expression. Feedback mechanisms, such as rewards or social recognition, can reinforce creative behavior and encourage further experimentation. Collaborative features enable players to share ideas, build upon each other's creations, and develop collective creativity. Finally, well-designed challenges can push players to think creatively, adapt to new situations, and generate innovative solutions (Kahila et al., 2020).

4.3.3 Collaboration

Research on collaboration in digital games has frequently referenced social constructivist, situated learning, and interdependence theory. Social constructivist theory emphasizes the role of social interaction and collaborative knowledge construction in learning, suggesting that players can develop collaboration skills by engaging in shared problem-solving and meaning-making within game environments (Vygotsky, 1978; Palincsar, 1998). Situated learning theory highlights the importance of authentic, context-rich experiences in fostering the development of collaboration skills that are transferable to real-world situations (Lave & Wenger, 1991; Brown et al., 1989). Interdependence theory stresses the role of positive interdependence, individual accountability, and promotive interaction in effective collaboration, which can be fostered through carefully designed game mechanics and challenges.

Multiplayer, role-playing, sandbox, and serious games have been identified as the most effective genres for promoting collaboration skills (Granic et al., 2014; Gee, 2003). Multiplayer games, by definition, require players to interact, communicate, and work together to achieve shared goals, providing rich opportunities for developing collaboration skills (Squire, 2011). Role-playing games often involve complex social interactions, negotiation, and teamwork, as players take on different roles and work together to overcome challenges (Whitton, 2014). Sandbox games, with their open-ended nature, allow players to collaborate

on creative projects, share resources, and build communities (Craft, 2011). Serious games can be designed to target specific collaboration skills, such as leadership, conflict resolution, or task coordination, through structured challenges and scenarios that require effective teamwork (Connolly et al., 2012).

Game design elements that have been highlighted for fostering collaboration include social interaction mechanics, narratives, collaboration mechanics, feedback, and challenges. Social interaction mechanics, such as chat systems, emotes, or shared spaces, provide players with tools to communicate, build relationships, and coordinate their actions. Narratives can create shared goals and experiences that encourage players to work together and develop a sense of camaraderie (Jenkins, 2004). Collaboration mechanics, such as shared resources, complementary abilities, or team-based challenges, create interdependence and encourage players to rely on each other's strengths (Rocha et al., 2008). Feedback systems, such as group rewards or performance indicators, can reinforce effective collaboration and help players identify areas for improvement (Hattie & Timperley, 2007). Finally, well-designed challenges that require communication, coordination, and collective problem-solving can foster the development of a wide range of collaboration skills (Steinkuehler, 2006).

4.3.4 Communication

Studies investigating communication skills in digital games have often drawn upon social constructivist and situated learning theories. Social constructivist theory emphasizes the role of social interaction and discourse in the construction of knowledge and the development of communication skills (Vygotsky, 1978). In digital games, players can engage in meaningful conversations, debates, and collaborative problem-solving, which can help them develop effective communication strategies (Gee, 2003). Situated learning theory highlights the importance of authentic, context-rich environments in fostering the development of communication skills that are transferable to real-world situations (Lave &

Wenger, 1991). Digital games can provide immersive, realistic scenarios that require players to communicate effectively to achieve shared goals or resolve conflicts (Shaffer et al., 2005).

Multiplayer, role-playing, sandbox, and serious games have been identified as the most promising genres for promoting communication skills (Granic et al., 2014). Multiplayer games inherently require players to communicate, whether through text, voice, or nonverbal cues, to coordinate their actions and achieve shared objectives (Steinkuehler & Williams, 2006). Role-playing games often involve complex social interactions and dialogue, allowing players to practice various communication styles and strategies. Sandbox games provide open-ended environments where players can engage in creative collaboration, share ideas, and negotiate shared projects (Scholten et al., 2017). Serious games can be designed to target specific communication skills, such as active listening, persuasion, or intercultural communication, through structured scenarios and challenges (Wouters et al., 2013).

Game design elements that have been highlighted for supporting communication include social interaction mechanics, narratives, collaboration features, feedback, and challenges (Hämäläinen et al., 2018). Social interaction mechanics, such as in-game chat, voice communication, or emotes, provide players with tools to express themselves and engage in meaningful conversations (Yee, 2006). Narratives can create shared experiences and contexts that encourage players to communicate and build relationships (Squire, 2006). Collaboration features, such as shared goals, team-based challenges, or co-creation tools, foster the need for effective communication and coordination (Bluemink et al., 2010). Feedback mechanisms, such as social rewards or performance indicators, can reinforce effective communication practices and help players identify areas for improvement (Habgood & Ainsworth, 2011). Finally, well-designed challenges that require clear communication, active listening, and persuasion can provide opportunities for players to practice and refine their communication skills in authentic, engaging contexts (Gee, 2005).

4.3.5 Critical Thinking

Research on critical thinking in digital games has often referenced constructivist, situated learning, and self-efficacy theories. Constructivist approaches emphasize the importance of active, learner-centered experiences in fostering critical thinking skills, as players engage in problem-solving, decision-making, and reflection within game environments (Kiili, 2005). Situated learning theory highlights the role of authentic, context-rich experiences in developing critical thinking skills that are transferable to real-world situations (Lave & Wenger, 1991). Self-efficacy theory suggests that players' beliefs in their own abilities to succeed in challenging tasks can influence their motivation and persistence in developing critical thinking skills (Bandura, 1997).

Serious games, role-playing games, and multiplayer games have been identified as the most effective genres for promoting critical thinking skills. Serious games can be designed to present players with complex, real-world problems that require the application of critical thinking skills, such as evaluating evidence, making informed decisions, and analyzing multiple perspectives (Gee, 2003). Role-playing games often involve complex moral dilemmas, strategic decision-making, and the need to consider long-term consequences, providing opportunities for players to practice critical thinking in immersive, narrative-rich contexts. Multiplayer games can foster critical thinking through collaborative problem-solving, debate, and the need to anticipate and respond to the actions of other players (Steinkuehler & Duncan, 2008).

Game design elements that have been highlighted for promoting critical thinking include interactivity, challenges, feedback, rewards, narratives, collaboration, and problem-solving opportunities. Interactive game environments allow players to make choices, experiment with different strategies, and observe the consequences of their actions, fostering the development of critical thinking skills (Yang, 2015). Well-designed challenges provide

opportunities for players to analyze complex problems, evaluate evidence, and make reasoned decisions (Erhel & Jamet, 2013). Immediate feedback helps players reflect on their choices and refine their critical thinking strategies (Kiili, 2007). Rewards and incentives can motivate players to persist in the face of challenging tasks and encourage the development of critical thinking skills (Qian & Clark, 2016). Narratives can present complex moral dilemmas and multiple perspectives, requiring players to think critically about their decisions and the potential consequences (Barab et al., 2010). Collaborative problem-solving in multiplayer settings can expose players to diverse viewpoints, encouraging them to evaluate arguments and engage in constructive debate (Chen & Hwang, 2017). Finally, open-ended problem-solving opportunities allow players to apply critical thinking skills in authentic, context-rich situations, promoting the transfer of these skills to real-world contexts (Hwang et al., 201).

Overall, the review highlights the prominence of constructivist learning theories, such as social constructivist and situated learning theory, in shaping the design of digital games. These theories emphasize the importance of active, experiential learning and the creation of sharable artifacts, recognizing learners as active constructors of knowledge rather than passive recipients of information (Papert & Harel, 1991; Vygotsky, 1978). By aligning digital game design with these principles, educators and digital game designers can create learning experiences that are engaging, meaningful, and conducive to skill development.

The review also reveals the diversity of digital game genres employed for targeting specific 21st-century skills, including serious games, role-playing games, simulation games, puzzle games, and sandbox games. This finding highlights the diversity of game-based learning approaches and suggests that different genres may offer unique affordances for promoting specific skills (Ke, 2016). For example, sandbox games, with their open-ended exploration and creativity-oriented gameplay, may be particularly effective for fostering

creativity and problem-solving skills, while role-playing games, with their immersive narratives and opportunities for social interaction, may be well-suited for promoting collaboration and communication skills (Dickey, 2011).

Furthermore, the review identifies several digital game design elements that have been incorporated into the included studies to support skill acquisition, such as challenges, feedback, rewards, social interaction, narratives, and customization options. These elements align with established principles of digital game design and learning theory that emphasize the importance of providing learners with appropriate challenges, immediate feedback, and opportunities for social interaction and collaboration (Gee, 2005; Plass et al., 2015). By carefully integrating these design elements, digital game designers can create digital games that are both engaging and effective for promoting 21st-century skills.

4.4 Implications and Future Directions

The findings of this systematic review have several implications for educators, researchers, and digital game designers. Firstly, the positive effects of digital games on 21st-century skills suggest that well-designed digital games can serve as tools for fostering critical skills in K-12 students. Educators should consider integrating purposefully designed digital games into their curricula, aligning them with learning objectives and subject-specific content to maximize their potential for skill development.

Secondly, researchers should continue to investigate the mechanisms through which digital games support skill development, employing research designs and exploring the long-term impacts of digital game-based interventions. Future studies should also examine the role of individual differences, such as prior gaming experience and learning preferences, in shaping the effectiveness of digital game-based learning experiences. By addressing these research gaps, scholars can contribute to a more comprehensive understanding of the conditions under which digital games are most effective for promoting 21st-century skills.

Additionally, it is important to consider the growing influence of artificial intelligence (AI) on various aspects of our lives, including education and the workforce. As AI technologies continue to advance, they are increasingly capable of automating tasks that previously required human thinking and creativity. The AI trend highlights the importance of fostering higher-order thinking skills, such as problem-solving, creativity, and critical thinking, in K-12 students to prepare them for a future where AI is more prevalent. Educational systems must adapt to this changing landscape by emphasizing the development of these skills alongside digital literacy and AI competencies. Digital game-based learning approaches, as demonstrated in this systematic review, can play a vital role in this process by providing engaging and effective means of cultivating 21st-century skills.

Finally, digital game designers should draw upon established learning theories and incorporate digital game design elements to create engaging and effective digital games that target 21st-century skills. By collaborating with educators and researchers, digital game designers can ensure that their products are aligned with curricular goals and are grounded in sound pedagogical principles (Hirumi et al., 2010). Additionally, digital game designers should consider the diverse needs and preferences of learners, creating digital games that offer personalized and adaptive learning experiences to optimize skill development (Plass et al., 2015).

4.5 Limitations

This review has some limitations to note. The search was restricted to five databases and to publications in English. Relevant studies in other databases or languages may have been missed. Additionally, we did not have access to the full text of all potentially relevant manuscripts identified in the search. The inclusion of these studies could have provided further insights and evidence.

5. Conclusion

In an era where the rapid evolution of technology continuously reshapes the educational landscape, this systematic review sheds light on the profound potential of digital games to enhance 21st-century skills among K-12 students. By examining research from 2014 to 2023, we have uncovered compelling evidence that well-designed digital games are not just mere tools of engagement but powerful mediums for fostering essential skills.

Our findings reveal that digital games, grounded in constructivist learning theories, offer versatile and adaptable platforms for diverse educational contexts. These games have demonstrated significant effectiveness across various educational levels, particularly in middle and high school settings. The careful integration of challenges, feedback, social interaction, and narrative elements within these games has proven instrumental in supporting skill acquisition and enhancing learning outcomes.

The implications of these insights are far-reaching. For educators, the integration of purposefully designed digital games into the curriculum represents a transformative approach to skill development. Such integration not only engages students but also provides them with the necessary tools to navigate and thrive in a complex world. Researchers are encouraged to delve deeper into the mechanisms through which digital games facilitate skill development and to explore their long-term impacts. This ongoing investigation will further solidify the role of digital games in education and provide a robust foundation for future innovations.

Digital game designers, on the other hand, are called to collaborate closely with educators and researchers. By doing so, designers can create games that are not only engaging and enjoyable but also deeply educational and effective. Drawing upon established learning theories and incorporating evidence-based design elements will ensure that these digital games meet the educational needs of the 21st century.

As we look to the future, the growing influence of artificial intelligence underscores the importance of equipping students with higher-order thinking skills. Digital game-based learning stands out as a vital strategy in this endeavor, offering dynamic and interactive ways to cultivate digital literacy and AI competencies alongside traditional academic skills.

In conclusion, this systematic review affirms the transformative potential of digital games in promoting 21st-century skills among K-12 students. By harnessing the power of digital games, educators, researchers, and designers can collaboratively create innovative learning experiences that not only captivate students but also prepare them for the demands of a rapidly changing world. The journey towards integrating digital games into education is not merely a trend but a necessary evolution, one that holds the promise of a more engaging, effective, and future-ready educational paradigm.

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Appendix A

Search strings per database.

Database	Search String	Number of Studies
Science Direct	All (("game")) AND (("learning")) AND (("21st-century skills"))	261
ERIC	((("Online game" OR "Video game" OR "Digital game" OR "Computer-based game" OR "game-based learning")) AND (("learning" OR "education" OR "elementary school" OR "student" OR "k-12 education" OR "secondary education")) AND (("21st-century skills" OR "21st-century skills" Or "twenty-first-century skills" OR "systemic thinking" OR "systems thinking" OR "problem solving" OR "critical thinking" OR "collaboration" OR "creativity" OR "communication" OR "information skills"))	362
Scopus	All (("game*")) AND (("learning")) AND (("21st-century skills"))	581
ProQuest	All (("game")) AND (("learning")) AND (("21st-century skills"))	595
Google Scholar	allintitle: game AND creativity OR "problem solving" OR collaboration OR communication OR "critical thinking"	970
Web of Science	((("Online game" OR "Video game" OR "Digital game" OR "Computer-based game" OR "game-based learning")) AND (("learning" OR "education" OR "elementary school" OR "student" OR "k-12 education" OR "secondary education")) AND (("21st-century skills" OR "21st-century skills" Or "twenty-first-century skills" OR "systemic thinking" OR "systems thinking" OR "problem solving" OR "critical thinking" OR "collaboration" OR "creativity" OR "communication" OR "information skills"))	299
TOTAL		3068