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REVIEW AND SYNTHESIS

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Assessing the benefits of digital game-based learning with Minecraft in children, adolescents and young adults: A broad systematic review

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Abstract

Minecraft is a popular digital game-based learning (DGBL) tool used in learning environments around the world. With increasing emphasis on evidence-informed practice and policymaking in educational systems, this paper systematically reviews the evidence base behind the use of Minecraft in improving academic, cognitive, motivational-affective and social outcomes. We searched seven databases and other secondary sources up until February 2024. Pre-post intervention studies that evaluated the use of Minecraft (randomised, non-randomised and single-group studies) in children, adolescents and young adults were included. Twenty-nine studies satisfied our inclusion criteria. Studies primarily investigated Minecraft as a tool to improve cognitive ($n=7$) and academic ($n=16$) outcomes. Studies reported positive effects on spatial thinking ($n=2$), creativity ($n=3$), critical thinking ($n=1$), mathematics ($n=5$), science ($n=4$) and language ($n=2$). However, all studies included in this review had a medium or high risk of bias. Therefore, while Minecraft demonstrates good potential in improving these outcomes, effects need to be replicated in more rigorous studies. Suggestions for future research are discussed.

This review provides timely evidence for educators, school leaders and policymakers regarding the use of DGBL with Minecraft.

KEYWORDS
digital game-based learning, Minecraft, systematic review

Context and implications

Rationale for this study: This paper reviews the effectiveness of Minecraft in improving learning outcomes.

Why the findings matter: It is critical for educators and policymakers to be aware of the evidence supporting the use of Minecraft as an educational tool. Additionally, this review offers insights into the learners, contexts and domains for which Minecraft is most beneficial.

Implications: There is promising evidence that digital game-based learning with Minecraft can improve cognitive and academic outcomes. However, the quality of the current evidence is limited, which restricts the claims we can make about its effectiveness. Moving forward, researchers should employ robust evaluations to determine its true effect. Funders and policymakers should emphasise the importance of rigorous evaluation in this area.

INTRODUCTION

Over the last two decades, the rise in digital games for entertainment among children, adolescents and young people has prompted investigation into their educational potential (Plass et al., 2015). The COVID-19 pandemic further increased interest in digital game-based learning (DGBL) as a learning tool (Lehane et al., 2021; Squire, 2022). Despite the growing enthusiasm for DGBL, its impact on learning and cognition varies across different digital games (Bavelier & Green, 2019; Dale & Shawn Green, 2017). Schrier (2018) suggests that appropriately designed digital games enhance learning experiences by meeting specific educational needs. Minecraft, a popular game for building in 3D, is widely used as a tool to support diverse learning areas across primary (e.g. Slattery et al., 2023), secondary (e.g. Callaghan, 2016) and higher education (e.g. Andersen & Rustad, 2022). The popularity and widespread use of Minecraft in learning environments highlights the need to determine the evidence behind its use. This study systematically reviews evidence on Minecraft's effectiveness in enhancing learning outcomes (cognitive, academic, motivational-affective and social outcomes) for children, adolescents and young adults. The paper first broadly discusses DGBL and then focuses on the value of Minecraft in educational settings.

DGBL

Play is a core part of human behaviour and is fundamental for learning and development, including social, emotional and academic skills (Plass et al., 2015; Weisberg et al., 2013).

Games are an organised form of play with a set of rules and objectives (Klopfer et al., 2009). DGBL is the use of digital games in educational settings (Breien & Wasson, 2021; Prensky, 2001). These games are typically interactive, involve a goal, require a response from the learner, and provide feedback to the learner on their progress (Plass et al., 2015; Wouters et al., 2013). DGBL includes off-the-shelf games developed for recreational purposes but used for learning purposes and special purpose games (or serious games) designed for learning (All et al., 2016). While games may differ in whether they were initially developed for entertainment or education, the essential activity of both game types is play.

DGBL effects

DGBL has become an increasingly popular approach to education, prompting researchers to examine its effects on learning in cognitive, academic, motivational-affective and social domains (e.g. Barz et al., 2023). Cognitive outcomes include, but are not limited to, fluid intelligence (our capacity to find solutions to problems independent of knowledge acquired in the past; Cattell, 1987) and executive functions (a set of interrelated processes responsible for goal-directed behaviour, such as attention, working memory and planning; Friedman et al., 2006; Gioia et al., 2015). These outcomes require effortful processing during assessment (Tucker-Drob et al., 2022) and are critical for students' academic performance (Peng & Kievit, 2020). Academic outcomes encompass knowledge and skills acquired through formal education including performance on schoolwork or coursework and related standardised tests (Wang et al., 2020). The assessment of academic outcomes requires the retrieval and application of previously acquired knowledge and includes domains such as reading and mathematics (Tucker-Drob et al., 2022). Sometimes academic outcomes are categorised as cognitive outcomes in the DGBL literature (e.g. Krath et al., 2021); however, acknowledging the difference between these outcomes allows for a clearer understanding of the effects of DGBL and the design of more effective interventions.

Another category relates to motivational-affective outcomes. Many outcomes fall under this category (Lesperance et al., 2022), such as interest, motivation and self-schema (e.g. self-efficacy, agency; Murphy & Alexander, 2000), which are influenced by affective factors (e.g. learners' emotional reactions; Pintrich, 2003). One of the most common arguments supporting DGBL is its motivational potential (Gee, 2007). Motivation is important for learners' academic progress and success (Rowell & Hong, 2013). DGBL may foster learners' intrinsic motivation (i.e. players play the game because it is inherently satisfying), which can help to develop self-directed learners (Garris et al., 2002). DGBL can also be extrinsically motivating (i.e. it provides positive external reinforcement) due to features like rewards (Huang et al., 2010).

Social outcomes include collaboration, teamwork and social competence, all of which are important social skills. DGBL can provide opportunities for social interaction and collaboration, where learners work together to achieve shared goals. This can involve students working together, delegating tasks and communicating effectively with one another (Slattery et al., 2023). Notably, previous research has shown that students' social skills (e.g. social competence and peer relationships) are linked to their academic achievements (Elias & Haynes, 2008).

Meta-analyses and systematic reviews have indicated mixed effects of DGBL and game-based learning on these learning outcomes. Some reviews report positive effects of DGBL interventions on cognitive (e.g. Behnamnia et al., 2020), academic (e.g. Young et al., 2012), motivational-affective (e.g. Vlachopoulos & Makri, 2017) and social (e.g. Qian & Clark, 2016) outcomes. However, other reviews do not report such effects. For example, Wouters et al. (2013) found that DGBL did not positively influence learners' motivation.

These mixed results may be due to large heterogeneity in methods for examining DGBL effects (All et al., 2016) and variations in game quality (All et al., 2021). As Schrader and McCreery (2012) highlight, digital games for learning differ in relation to the learning content, how this content is communicated (i.e. game design features and the learning theory that informs the design of the game) and how learners interact with them (i.e. technological tools). The effects of DGBL have been shown to vary across these game characteristics (Clark et al., 2016). Thus, digital games likely differ with respect to their potential impact on learning (Bavelier & Green, 2019; Dale & Shawn Green, 2017). This highlights the need for game-specific investigations to identify effective DGBL tools.

DGBL with Minecraft

Since its release in 2011, Minecraft has become one of the bestselling digital games (Minecraft, 2021). Minecraft is a sandbox game, which provides players with a great degree of freedom and creativity in terms of its gameplay, as there are no predetermined goals. Players can explore virtually infinite 3D 'worlds' that consist of cubic blocks. The blocks represent different materials such as stone, water and lava. The game worlds comprise biomes (characterised by distinct geological features and species) such as deserts, jungles and mountains. The core element of play within the game involves players constructing 3D structures. Its popularity and flexibility in terms of game design and play led to a significant increase in the use of Minecraft-based DGBL in educational settings (e.g. Callaghan, 2016). To date, Minecraft has been used to improve a range of outcomes, including cognitive (e.g. critical thinking; Rich, 2016), academic (e.g. STEM; Hobbs, Bentley, et al., 2020), motivational-affective (e.g. engagement; Tromba, 2013) and social (e.g. collaboration; Abrahams, 2018). Moreover, it has been used with learners of various ages, from primary school (e.g. Slattery et al., 2023) through to third level (e.g. Bourdeau et al., 2021).

Educators' interest in Minecraft for teaching and learning prompted the launch of Minecraft Education in 2016. Minecraft Education is a special-purpose DGBL platform designed for use in learning environments. This version has the same core gameplay (i.e. creating 3D structures), but it has many additional features for easier use in educational settings (e.g. students can work on projects in the same world). Moreover, it contains lessons for various subjects, which can be used to supplement the curriculum (Callaghan, 2016). The versatile nature of the platform allows educators to adapt the game to fit their own needs and objectives, design their own lessons and customise their students' learning experiences (Lehane et al., 2021).

Minecraft Education is widely used across the world. As of October 2021, over 35 million teachers and students were licensed to use the platform in 115 countries (Minecraft, 2021). The platform is freely available in several educational systems, including those in Northern Ireland (Minecraft Education, 2022) Australia (NSW Department of Education, n.d.) and United Arab Emirates (National News, 2022). Various initiatives have been run to encourage its use. For example, in 2021, a national project-based initiative was launched in Ireland called Ireland's Future is MINE, which required classes to design a sustainable version of their local community using the platform (for more information see, Slattery et al., 2023). Notably, some of these initiatives are government supported. For instance, the Welsh Department of Education and Skills established several schools as 'Minecraft Learning Centres' in 2019 to spread their knowledge in using Minecraft Education as an educational tool (Minecraft Education, n.d.). However, despite its popularity and widespread use, educational researchers, practitioners and school leaders must understand the evidence base behind the use of Minecraft in education to integrate it in a meaningful and effective way.

DGBL with Minecraft has the potential to target multiple learning outcomes (e.g. cognitive and social outcomes; Callaghan, 2016). This may be because DGBL with Minecraft can support several key principles across various learning theories. At the outset of this section, it is important to note that the extent to which DGBL with Minecraft supports these learning theories depends on how the game is implemented for learning purposes. First, learning with Minecraft can be viewed from social and cultural perspectives, such as the social learning theory (Bandura, 1977), given that Minecraft is typically a social game. That is, learners interact with one another and engage in behaviours like observation and modelling, which can support learning. When viewed from a constructivist learning perspective (Piaget, 1977), DGBL with Minecraft enables learners to actively participate in their learning experiences, facilitating knowledge creation. This is achieved in the game through learners or teachers setting challenges, constructing a response to that challenge and receiving feedback on their response (Plass et al., 2015). In line with Papert's constructionism approach to learning, the artefacts that learners construct in Minecraft become 'objects to think with' that can be shared and discussed with others, which can facilitate effective learning (Papert, 1980, p. 12). Another potential account for how Minecraft influences learning is that of neuroplasticity, which refers to the brain's ability to adapt to its environment. Repetitive gameplay of constructing structures provides opportunities to exercise various cognitive functions like spatial thinking, creativity and problem-solving. Finally, learning with Minecraft can be viewed from a motivational perspective. For example, the self-determination theory focuses on three processes underlying motivation – autonomy, competence and relatedness (Chen & Jang, 2010; Ryan & Deci, 2017). Minecraft may enhance one or more of these processes, which in turn may increase learning outcomes. Thus, various theories can be used to understand how learning can occur with Minecraft. However, to understand if and how different outcomes can be affected by Minecraft-based DGBL, we must carefully examine relevant empirical research.

Criteria for evaluating DGBL interventions

All et al. (2016) outlined a set of overarching practices to improve the rigour of DGBL intervention evaluation studies. These practices include recommendations relating to (1) research design (e.g. use of an education-as-usual control group, pre-test, randomisation and follow-up assessment), (2) intervention (e.g. including a training session, DGBL as a standalone intervention), (3) participants (minimum of 20 per group), (4) measures (e.g. valid and reliable measures) and (5) data analysis (e.g. repeated measures; for more detail, see All et al., 2016). While others have outlined 'best practices' for evaluating behavioural interventions (e.g. Simons et al., 2016), those from All et al. (2016) are specific to DGBL, which makes them applicable for Minecraft DGBL intervention studies. This review uses these standards to appraise the quality of each study and to identify the conclusions that can be made about the effectiveness of DGBL with Minecraft.

The current review

This study expands on earlier reviews by specifically investigating DGBL with Minecraft, and critically evaluates studies based on criteria for evaluating DGBL interventions, as recommended by All et al. (2016). We focused on the following question:

1. Do DGBL interventions with Minecraft improve cognitive, academic, motivational-affective and social outcomes in children, adolescents and young adults?

To address this question, we will review studies that assess the effectiveness of DGBL interventions with Minecraft by measuring their impact on outcomes. We chose a broad question to comprehensively capture the available evidence that measures the effect of DGBL interventions with Minecraft.

METHOD

This systematic review is reported in accordance with recommendations outlined in the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Statement (Page et al., 2021). The review protocol was prospectively registered on the Open Science Framework (OSF; https://osf.io/2y6xc/).

Search strategy and systematic search procedures

Seven databases (PubMed, PsycINFO, Web of Science, The Cochrane Library, ERIC, Education Research Complete and Scopus) were initially searched on November 17, 2021. The search strategy included terms for Minecraft in the titles and abstracts of articles. The search parameters were not restricted. We consulted with a librarian who guided the development of a comprehensive search strategy. Supplementary secondary searches were also conducted via Google Scholar, Open Grey and the OSF. The reproducible search strategy and hits for each database and secondary searches can be accessed in Appendix A. Database searches were re-run in December 2022 and February 2024 to update the initial search. All studies included at full-text were forward citation chased. The search results were imported into EndNote. We strengthened the validity of our findings by: (1) applying a priori inclusion and exclusion criteria to select studies relevant to our research question, and (2) developing a comprehensive search strategy in consultation with a librarian.

Eligibility criteria

The a priori inclusion/exclusion criteria are presented in Table 1.

Note, studies that included children, adolescents and young adults were included given that DGBL with Minecraft is used across various learning contexts including adolescents in secondary school (e.g. Nkadimeng & Ankiewicz, 2022) and young adults in third-level education (e.g. Bourdeau et al., 2021). Samples with a mean age ≤ 30 years were selected due to variations in the age range of young adults in the literature and align with other reviews (e.g. Shannon et al., 2022). This age group was included to capture studies of Minecraft in higher education settings. Qualitative studies were excluded from this review because they do not test the effect of an intervention by measuring outcomes, which was the primary focus of this research. Single case studies were excluded because these designs typically do not report group-level data or examine patterns across groups or participants in relation to outcomes.

Screening

The results from the database searches were transferred into EndNote where duplicates were removed. The remaining articles were then exported to Covidence. At the start of the title and abstract screening process, we implemented an initial training/piloting period, reviewing 5% of the papers to ensure consistency before proceeding with full screening.

TABLE 1 Inclusion/exclusion criteria.

Criteria	Inclusion	Exclusion
Digital game	Minecraft was used as a primary tool or in combination with other tools	Studies that did not report the use of Minecraft (i.e. Pradiante, 2022)
Outcome measures	Studies that investigated digital games involving at least one academic, cognitive, motivational-affective and social outcome	Studies that investigated digital games outside these domains (e.g. Wright & Weidman, 2018)
Study design	Randomised studies Non-randomised studies One-group uncontrolled studies Pre-post interventions	Studies that did not collect or report pre- and/or post-data for relevant outcomes (e.g. Cateté et al., 2014; Saito et al., 2016) Single case studies (e.g. Worsley & Bar-El, 2020)
Sample	Children, adolescents and young adults (mean age ≤ 30 years)	Studies involving adults (mean age > 30 years; e.g. Stark et al., 2021) Samples with ≤10 participants per group (e.g. Moffat et al., 2017)
Language	Articles written in English	Other languages were not included (e.g. Duris et al., 2022)

In our initial search, the title/abstracts of all studies were screened by two independent reviewers ($N=793$) resulting in an inter-rater reliability (Cohen's kappa) of 0.76. This suggests that there was adequate inter-rater reliability between the two reviewers at this stage. Articles that met the inclusion criteria were selected for full-text screening. Full-text screening was initially completed by two independent reviewers. Conflicts between reviewers were resolved via discussion and consensus. This involved each reviewer explaining their rationale for deciding to include or exclude an article at the full-text stage. The PRISMA flow is presented in Figure 1.

Data extraction

Covidence was used for data extraction. Data were extracted under the following headings: general information, characteristics of included studies, outcomes, statistical analysis, results and limitations. The first author performed data extraction. Expert opinion from the first and second authors, who hold PhDs in Psychology and Educational Assessment respectively, was used to categorise the outcomes.

Risk of bias

The Evidence Project risk of bias tool (Kennedy et al., 2019) was used to rate the methodological characteristics of included studies. This tool is designed to assess the risk of bias in quantitative intervention studies (Kennedy et al., 2019) and therefore aligns with our research question. This eight-item tool was chosen as it is a brief instrument that could evaluate the various intervention study designs (i.e. experimental, quasi-experimental and single-group pre-test post-test designs) included in the review. For each item, the rater assigns a score indicating its presence (yes) or absence (no) and in some cases, indicates if it is not applicable/not reported (Kennedy et al., 2019). The eight items include: '(1) cohort, (2) control or comparison group, (3) pre-post intervention data, (4) random assignment of participants to the

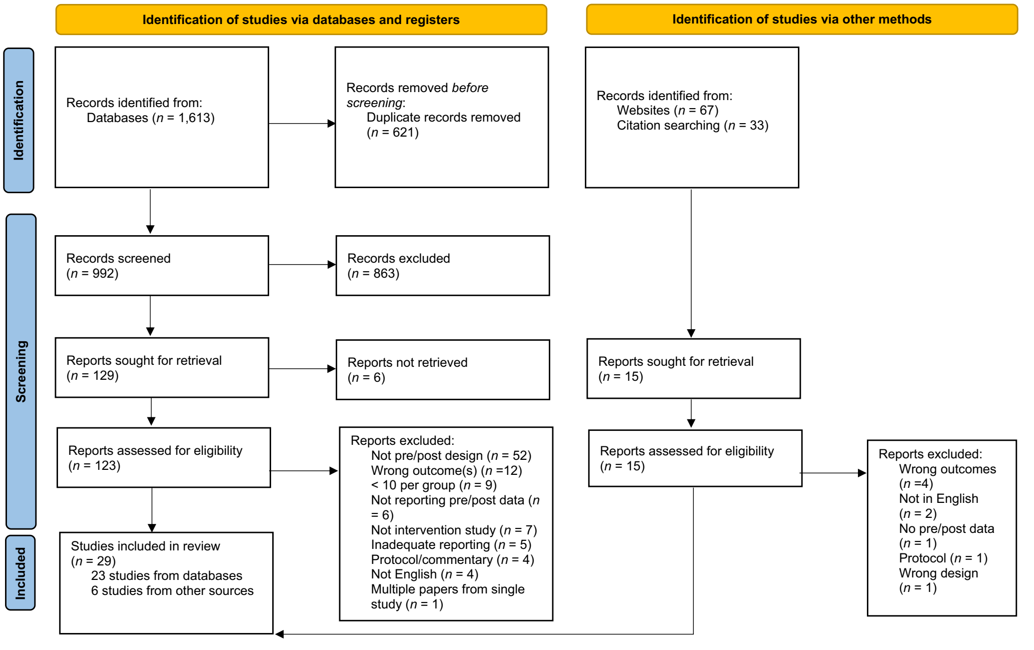

FIGURE 1 Prisma flow.

intervention, (5) random selection of participants for assessment, (6) follow-up rate of 80% or more, (7) comparison group equivalent on sociodemographics and (8) comparison groups equivalent at baseline on outcome measures' (Kennedy et al., 2019, p. 3). More information on each item can be found in Kennedy et al. (2019). Raters assigned one point per criterion fulfilled and zero points if it was not met. Scores were summed to provide an estimate of each study's risk of bias. Higher scores indicate less risk of bias. Scores were categorised into high (0–2), medium (3–5) and low (6–8) risk of bias. In line with recommended guidelines (Boutron et al., 2022), to address risk of bias in the results, we stratify the studies according to our evaluation of overall risk of bias. The potential for bias should be taken into consideration when interpreting any reported effects. The first and second authors completed the risk of bias assessment on 20% of the articles to ensure consistency. The first author then assessed the remaining articles, consulting with the second author to resolve any ambiguities where they arose.

REVIEW

In total, 29 studies satisfied our inclusion criteria (23 studies from database searches and six studies from other sources). Twenty studies were identified in our initial search in November 2021, two studies were identified in December 2022 (Kutay & Oner, 2022; Pirlet, 2021) and seven studies were identified in February 2024 (Abdalkader, 2023; Gadbury & Chad Lane, 2023; Grobelina et al., 2022; Kersánszki et al., 2023; Li & Wang, 2023; Qu et al., 2023; Tablatin et al., 2023). A summary of each study included in the review can be found in Appendix B. Most studies evaluated the impact of Minecraft on cognitive and academic outcomes and reported positive effects; however, all studies had medium or high risk of bias. The majority of studies ($n = 24$) were categorised as medium risk of bias (i.e. scores ranging from 3 to 5). The remainder of studies had a high risk of bias (scores ranging from 0 to 2). No studies were categorised as low risk of bias. Table 2 describes the characteristics of each study and Table 3 displays the

TABLE 2 Intervention characteristics for each study.

First author	Year	Sample (N)	Age (years)	% male	Place	Design (groups)	Intervention (n)	Minecraft version	Setting	Duration	Comparator (n)
Cognitive outcomes											
Carbonell-Carrera	2021	University students (N=34)	21.81	59%	Spain	CT (two-group)	Participants translated between 2D and 3D representations and built their ‘dream house’ in Minecraft, drawing this in both 3D and 2D (n=17)	Minecraft	NR	Approx. 240 min (2 sessions)	Passive control (n=17)
Sariçam	2021	Children (N=25)	NR class 6	72%	Turkey	Single-group	Students completed STEM activities that required them to create solutions to problems in Minecraft	Minecraft Education	School	960 min (4 h per week for 4 weeks)	–
Melián Díaz	2020	University students (N=15)	25–35	40%	Spain	Single-group	Workshop: Participants drew a 3D object and constructed the object in Minecraft. Participants then built the house of their dreams in Minecraft and drew the house in both 3D and 2D	Minecraft	NR	240 min (2 sessions)	–
Lux[a,d]	2019	Children (Yr 1, N=32; Yr 2, N=28)	class 4-7	Yr1: 74% Yr2: 50%	United States	Single-group	Summer camp: Participants completed activities designed to simulate 3D rotations and train 2D to 3D spatial reasoning within Minecraft	Minecraft	Camp	NR (2 days)	–
Smith	2019	Young adults (N=22)	24.59 (5.05)	50%	Australia	Single-group	Virtual reality task in Minecraft: Participants built their own version of a house from a target picture	Minecraft	Lab	15 min	–
Sun[d]	2019	Adolescents (N=20)	NR class 7	NR	China	Single-group	Programming intervention: Students used Python in Minecraft (e.g. to build a house). Minecraft was used in combination with other materials and activities	Minecraft	School	1080 (1.5 h per week for 12 weeks)	–
Checa-Romero	2018	Adolescents (N=85)	12–15	55%	Spain	Single-group	Creativity intervention: Participants built the ‘house of their dreams’ in Minecraft and then created a video that demonstrated their creations	Minecraft	School	NR (8 sessions)	–
Academic outcomes											
Abdalkader[e]	2023	Adolescents (N=33)	15	NR	Egypt	Single-group	Minecraft was ‘modded’ by AI tools (i.e. Grammarly AI app) to hold discussions and pose questions to students	Minecraft	School	2880 min (24 sessions)	–

(Continues)

TABLE 2 (Continued)

First author	Year	Sample (*N*)	Age (years)	% male	Place	Design (groups)	Intervention (*n*)	Minecraft version	Setting	Duration	Comparator (*n*)
Grobelina	2023	University students (*N*=51)	Mean age=20 years	100%	Poland	CT (two groups)	1. Students were taught to integrate Petri nets with Minecraft for simulating physical systems, then applied this individually or in groups for 90 min. Students were asked to independently experiment with more detailed and complex setups over a week 2. Students were introduced to using Perti nets with Minecraft to simulate machinery, then applied this individually or in groups for 90 min	Minecraft	University	180 min (2 sessions)	Control: Traditional instruction received (note, the control group completed the assessed at post-test only)
Kersanszki	2023	Adolescents (*N*=15)	10–16 years	93%	Hungary	Single-group	Participants designed, built and explored power plants/energy sources	Minecraft	Camp	NR	–
Li[d]	2023	Children (*N*=30)	9–12 years	NR	China	CT (two groups)	The aim was for students to build a scaled-down agricultural landscape in Minecraft based on local geomorphic features. Students had an initial session on agriculture, were introduced to Minecraft and researched local terrains. They shared their knowledge, created paper-based designs, and then built their prototypes in Minecraft. Finally, they presented their constructions using screencasts	Minecraft	School	NR	Control: Traditional agricultural teaching
Qu[b,d]	2023	Adolescents (*N*=60)	High school students (age NR)	NR	China	CT (two groups)	Students used Python code to complete actions in Minecraft	Minecraft	School	NR	Control: Traditional instruction
Kutay	2022	Children (*N*=20)	NR class 5 students	45%	Turkey	Single-group	Coding/computational thinking intervention: Minecraft was used to teach students coding. Activities were adapted from the Minecraft: Education Edition MadeCode curriculum. Examples of computational thinking concepts included sequences, events and loops	Minecraft Education	Univers-ity	360 min (6 sessions)	–

TABLE 2 (Continued)

First author	Year	Sample (*N*)	Age (years)	% male	Place	Design (groups)	Intervention (*n*)	Minecraft version	Setting	Duration	Comparator (*n*)
Pirlet[e]	2021	Adolescents (*N*=25)	NR class 10–12	40%	United States	Single-group	DBGL economics intervention: The game was modified (e.g. resource specialisation, predetermined land plots, movement restrictions and a central trading area) to incorporate economic concepts, such as opportunity cost, global trade, and supply and demand	Minecraft Education		1080 min (24 sessions)	–
Rader	2021	University students (*N*=25)	21–35	75%	United States	Single-group	Virial field camp in Minecraft: The camp mirrored the 3D geospatial components of geologic mapping. Participants completed various activities such as mapping. Minecraft was used with other materials	Minecraft	Online	NR (4 sessions)	–
Sudarmaji	2021	Children (*N*=63)	NR class 5	NR	Indonesia	CT (two groups)	Vocabulary intervention: Designed to develop students' vocabulary mastery. Little-to-no information is provided on the actual intervention (*n*=31)	Minecraft	School	60 min (4 sessions)	Control: Conventional vocabulary instruction (*n*=32)
Tangkui[c]	2021	Children (*N*=65)	NR class 5 students	NR	Malaysia	CT (two groups)	Fraction intervention: Participants completed various fraction problem-solving activities in various Minecraft worlds (*n*=31)	Minecraft	School	NR (7 sessions)	Control: Traditional faction instruction (*n*=34)
Aridi[d]	2020	Children (*N*=10)	9–11	NR	Lebanon	Single-group	Geometry intervention: Participants were shown how to navigate and build in Minecraft and then completed various tasks (no further information provided)	Minecraft Education	School	NR (10 sessions)	–
Hobbs	2020	Children (*N*=68)	9–10	44%	UK	Single-group	'Science Hunters' coral reef intervention: Participants were introduced to corals and threats to coral reefs, and explored coral reefs in Minecraft or constructed their own coral reef	Minecraft	School	NR	–

(Continues)

TABLE 2 (Continued)

First author	Year	Sample (*N*)	Age (years)	% male	Place	Design (groups)	Intervention (*n*)	Minecraft version	Setting	Duration	Comparator (*n*)
Hobbs	2019	Children/ adolescents ($N=492$)	7–14	57%	UK	Single-group	Comprised two separate 'Science Hunters' interventions. 1. Volcano intervention: Participants were introduced to volcanic rock samples and then completed a building challenge in Minecraft (e.g. build a volcano; $n=269$) 2. Habitats intervention: Animal adaptations in different environments were discussed and linked to biomes/animals in Minecraft. Participants then designed or built an animal that would live in a Minecraft world ($n=223$)	Minecraft	School	NR (1 session)	–
Koivisto[d]	2019	Children ($N=60$)	7–12	85.5%	Finland	Single-group	Programming intervention: Participants were required to programme robots for reconstructing the earth using Earth 2.0 Minecraft	Minecraft Earth	After school club	360 min (4 sessions)	–
McCashin	2019	Children ($N=77$)	9–11 years	87%	Canada	Single-group	Computer science summer camp: Participants played in a traditional Minecraft setting, created their own game worlds within Minecraft, and then worked through a Minecraft math intervention activity (focused on perimeter, area and volume)	Minecraft	Camp	NR (1 week)	NA
Craft	2016	Adolescents ($N=49$)	13–18	57%	United States	Single-group	History intervention (two iterations): In the first iteration, participants selected an ancient building in Rome, researched it and recreated it using Minecraft. In the second iteration, the building was provided to students	Minecraft Education	School	540 min per iteration (6 classes)	NA
Other outcomes											
Gadbury[d]	2023	Adolescents ($N=96$)	11–15 years	68%	US	Single-group	The camp involved exploring and building in custom build Minecraft worlds that focused on topics like astronomy and earth science in the game and included 'What if' questions	Minecraft: Java Edition	Camp	900 min (5 × 3-h meetings)	–

TABLE 2 (Continued)

First author	Year	Sample (*N*)	Age (years)	% male	Place	Design (groups)	Intervention (*n*)	Minecraft version	Setting	Duration	Comparator (*n*)
Tablatin	2023	Adolescents (*N*=117)	13–14 years	45.3%	Philippines	Single-group	The intervention involved What-If hypothetical implementations in Minecraft (i.e. a set of Minecraft worlds such as a 'Rocket Launch from Earth' modelled after NASA). Participants explored these worlds and made various observations	Minecraft	School	NR	–
Samsudin	2022	Children (*N*=33)	12	NR	Malaysia	Single-group	Participants built and created structures/worlds based on several themes (e.g. sustainability)	Minecraft Education	School	900 min (10 sessions over 10 weeks)	–
McColgan	2018	University students (*N*=55)	NR	33%	United States	Single-group	Pre-service teacher intervention (using games/Minecraft for teaching): Participants practiced playing Minecraft, experienced two example lessons, developed their own Minecraft environment, and presented their lessons	Minecraft	Class project	1260 min	–
Opmeer	2019	Adolescents (*N*=101)	12–15	NR	Nether-lands	CT (two groups)	Sustainable spatial planning intervention: Participants completed a project-based assignment that required participants to use Minecraft to research, design and build a sustainable development of islands (*n*=56)	Minecraft Education	School	3200 min (64 lessons over 16 weeks)	Control: Participants completed the same task but used pen and paper (*n*=45)
Zhu[d]	2017	Adolescents (*N*=50)	13.4 (1.2)	48%	Hong Kong	Single-group	Chinese history intervention: Participants completed various tasks in worlds and re-created places in Minecraft (e.g. the Forbidden City and the Chinese imperial palace for the Ming and the Qing dynasties)	Minecraft Education	School	3 h (3 sessions in total)	–

Abbreviations: CT, controlled trial; NR, not reported; RCT, randomised-controlled trial.

[a]The results of this study are reported across three conference papers: Lux (2019), Hughes, Bentley, et al. (2020) and Hughes, Hartley, et al. (2020).

[b]This paper states that participants were randomly assigned to groups; however, the study is described as a quasi-experimental design, so we categorised it as a controlled trial.

[c]The results of this study are reported across two papers: Tangkui and Keong (2021) and Tangkui and Keong (2023).

[d]Conference proceedings/papers.

[e]PhD thesis.

TABLE 3 Intervention effects and methodological characteristics.

		Measures												
		Cognitive Outcomes				Academic Outcomes			Other Outcomes					
First Author	Year	Creativity	Spatial skills	Critical thinking	Response inhibition	Math-related	Science-related	Language-related	Self-efficacy	Attitude / interest	Affect	Collaboration	21st Cen skills
Carbonell-Carrera	2021		blue										
Sariçam	2021	blue								blue			
Melián Díaz	2020	striped blue											
Lux [a]	2019		blue										
Smith	2019				red								
Sun	2019			blue					blue	blue			
Checa-Romero	2018	striped blue											
Abdalkader	2023							blue					
Grobelina [b]	2023												
Kersanszki [b]	2023												
Li	2023						blue			blue			
Qu	2023					blue							
Kutay	2022					blue							
Pirlet [b]	2021												
Rader	2021						blue						
Sudarmaji	2021							blue					
Tangkui [c]	2021					blue							
Aridi	2020					blue							
Hobbs	2020						blue						
Hobbs	2019						blue						
Koivisto	2019					blue							
McCashin	2019					red							
First Author	Year	Creativity	Spatial skills	Critical thinking	Response inhibition	Math-related	Science-related	Language-related	Self-efficacy	Attitude / interest	Affect	Collaboration	21st Cen skills
Craft [b]	2016												
Gadbury	2023									striped red			
Tablatin	2023									blue			
Samsudin	2022												blue
Opmeer	2019										blue		
McColgan	2018								blue				
Zhu	2017									striped blue			

Note: Block blue = positive effects with medium risk of bias; block red = no effects with medium risk of bias; striped blue = positive effects with high risk of bias; striped red = no effects with high risk of bias; blank = not investigated; Cen = century.

[a]The results of this study are reported across three conference papers Lux (2019), Hughes, Bentley, et al. (2020) and Hughes, Hartley, et al. (2020).

[b]No inferential statistics are reported.

[c]The results of this study are reported across two papers: Tangkui and Keong (2021) and Tangkui and Keong (2023).

reported effects. Risk of bias results are presented in Table 4. Below we review studies according to the summary of risk of bias and the outcomes investigated.

Studies with medium risk of bias

Twenty-four studies had a medium risk of bias (Abdalkader, 2023; Aridi & Saad, 2020; Carbonell-Carrera et al., 2021; Grobelina et al., 2022; Hobbs, Hartley, et al., 2020; Hobbs et al., 2019; Kersánszki et al., 2023; Koivisto et al., 2019; Kutay & Oner, 2022; Li & Wang, 2023; Lux, 2019; McCashin et al., 2019; McColgan et al., 2018; Opmeer et al., 2019; Pirlet, 2021; Qu et al., 2023; Rader et al., 2021; Saricam & Yildirim, 2021; Samsudin et al., 2022; Smith & Burd, 2019; Sudarmaji & Yusuf, 2021; Sun & Li, 2019; Tablatin et al., 2023; Tangkui & Keong, 2021).

Cognitive outcomes

Five studies that investigated the impact of Minecraft on cognitive outcomes were categorised as medium risk of bias (Carbonell-Carrera et al., 2021; Lux, 2019; Saricam & Yildirim, 2021;

TABLE 4 Evidence project risk of bias assessment tool.

First author	Year	Cohort	Control/ comparison	Pre-/post-intervention data	Random assignment (group or individual)	Participants randomly selected for assessment	Follow-up rate≥80%	Comparison groups equivalent on socio-demographics	Comparison groups equivalent at baseline on outcomes	EP RoB Score
Cognitive outcomes										
Carbonell-Carrera	2021	Yes	Yes	Yes	No	No	Yes	NR	NR	4 (Medium)
Sariçam	2021	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Melián Díaz	2020	Yes	No	Yes	NA	No	NR	NA	NA	2 (High)
Lux	2019	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Smith	2019	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Sun	2019	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Checa-Romero	2018	Yes	No	Yes	NA	No	NR	NA	NA	2 (High)
Academic outcomes										
Abdalkader	2023	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Grobelina	2023	Yes	Yes	Yes	No	No	NR	No	No	3 (Medium)
Kersanszki	2023	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Li	2023	Yes	Yes	Yes	No	No	Yes	No	NR	4 (Medium)
Qu	2023	Yes	Yes	Yes	NC	No	Yes	No	Yes	5 (Medium)
Kutay	2022	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Pirlet	2021	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Rader	2021	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Sudarmaji	2021	Yes	Yes	Yes	No	No	NR	NR	NR	3 (Medium)
Tangkui	2021	Yes	Yes	Yes	No	No	Yes	NR	NR	4 (Medium)
Aridi	2020	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Hobbs	2020	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Hobbs	2019	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Koivisto	2019	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
McCashin	2019	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Craft	2016	Yes	No	Yes	NA	No	NR	NA	NA	2 (High)

(Continues)

TABLE 4 (Continued)

First author	Year	Cohort	Control/ comparison	Pre-/post-intervention data	Random assignment (group or individual)	Participants randomly selected for assessment	Follow-up rate≥80%	Comparison groups equivalent on socio-demographics	Comparison groups equivalent at baseline on outcomes	EP RoB Score
Other outcomes										
Gadbury	2023	Yes	No	Yes	NA	No	No	NA	NA	2 (High)
Tablatin	2023	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Samsudin	2022	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Opmeer	2019	Yes	Yes	Yes	No	No	No	NR	Yes	4 (Medium)
McColgan	2018	Yes	No	Yes	NA	No	Yes	NA	NA	3 (Medium)
Zhu	2017	Yes	No	NR	NA	No	Yes	NA	NA	2 (High)

Abbreviations: NA, not applicable; NC, not clear; NR, not reported.

Smith & Burd, 2019; Sun & Li, 2019). These studies examined the impact of Minecraft on spatial thinking (Carbonell-Carrera et al., 2021; Lux, 2019), creativity (Saricam & Yildirim, 2021), response inhibition (Smith & Burd, 2019) and critical thinking (Sun & Li, 2019). All studies reported positive effects.

Spatial reasoning

Carbonell-Carrera et al. (2021) reported improvements in spatial skills (assessed using a Mental Rotation Test) following two sessions (approx. 240 min duration) using Minecraft. In this study, university students were assigned to an intervention group ($n=17$) or passive control group ($n=17$). The first session briefly introduced students to Minecraft. The second session included a training activity (translated between 2D and 3D representations) and a 'dream house' activity (involved participants building their 'dream house' in Minecraft and drawing this in both 2D and 3D). The intervention group demonstrated statistically significant improvements in spatial skills ($p<0.001$, $d=0.82$), whereas the control group did not ($p=0.07$). In another study, Lux (2019) reported statistically significant improvements in mental rotation (assessed using an adapted version of the Purdue Spatial Visualisation test) scores at post-test compared to pre-test in middle school students. In Twenty-seven students completed a two-day summer camp with Minecraft-based activities designed to simulate 3D rotations and train 2D to 3D spatial reasoning. No improvements were found for 2D to 3D transformation scores (assessed using a 2D to 3D transformation test adapted from the Spatial Reasoning Instrument).

Creativity

Saricam and Yildirim (2021) reported significant improvements (all *p*s reported as $p<0.05$) students' creativity (age 11-12 years; $N=25$; assessed using the Scientific Creativity Scale) following an educational intervention (960 min) in which students created solutions to various STEM problems (i.e. design plant cell models) in Minecraft Education.

Response inhibition

Smith and Burd (2019) reported no changes in response inhibition or activation (assessed using a cued go/no-go task) following a brief one-session virtual reality Minecraft intervention with young adults ($N=22$) that required participants to build a house.

Critical thinking

Sun and Li (2019) reported improvements in seventh class students' ($N=20$) critical thinking skills (assessed using self-report ratings) following a 12-week programming course (1080 min) in which students used Python in Minecraft to complete various tasks (e.g. build a house). Note, this intervention used Minecraft in combination with other materials and activities.

Academic outcomes

Fifteen studies that investigated the impact of Minecraft on academic outcomes were categorised as medium risk of bias (Abdalkader, 2023; Aridi & Saad, 2020; Grobelina et al., 2022; Hobbs, Bentley, et al., 2020; Hobbs et al., 2019; Kersánszki et al., 2023; Koivisto et al., 2019; Kutay & Oner, 2022; Li & Wang, 2023; McCashin et al., 2019; Pirlet, 2021; Qu et al., 2023; Rader et al., 2021; Sudarmaji & Yusuf, 2021; Tangkui & Keong, 2021). Out of these studies, seven studies examined mathematics-related outcomes, five studies examined science-related outcomes and three studies examined other academic outcomes.

Mathematics-related outcomes

Two studies examined changes in students' geometry knowledge (Aridi & Saad, 2020; McCashin et al., 2019). In a single-group study, Aridi and Saad (2020) reported an improvement in geometry knowledge ($p < 0.001$; assessment not reported) in a sample of children ($N = 10$; 9–11 years) following 10 sessions (duration not reported) in Minecraft Education (very little detail was provided on the intervention). McCashin et al. (2019) also used a single-group design to examine changes in students' ($N = 77$) understanding of geometry (assessed using an original instrument) after a five-day Minecraft summer camp; however, no improvements were found. During the camp, students played Minecraft in the traditional sense, created their own worlds and completed a Minecraft-based mathematics activity, which focused on perimeter, area and volume.

Three studies examined the impact of Minecraft on computational thinking (Koivisto et al., 2019; Kutay & Oner, 2022; Qu et al., 2023). Kutay and Oner (2022) investigated the impact of a Minecraft Education coding intervention on students' ($N = 20$) computational thinking skills (aged 10-11 years). Over six weeks, students were introduced to new coding concepts (e.g. loops) and completed related activities using the platform. The outcome measure was knowledge of computational concepts assessed using a computational learning test with Scratch (pre-test) and a computational learning test with Minecraft Education (post-test). The results indicated that scores significantly improved from pre-test to post-test ($p < 0.01$). Koivisto et al. (2019) examined the impact of Earth 2.0 Minecraft (an augmented reality game based on Minecraft) delivered as part of an afterschool programming intervention for 62 children aged 7–12 years (Koivisto et al., 2019). In the game, children were required to programme robots to reconstruct the earth over four sessions. The paper reported significant improvements in computational thinking (a conceptual knowledge test developed by the researchers) following four sessions. In another study, Qu et al. (2023) examined the impact of a Python lesson using Minecraft on high-school students' ($N = 60$) computational thinking skills (assessed using a self-report scale) using a between-subjects design. At post-test the intervention group had significantly higher scores than the control group, suggesting the lesson improved computational thinking.

Tangkui and Keong (2021) reported improvements in Year 5 students' ability to solve fractions. Students were assigned to an intervention group ($n = 31$) or a control group ($n = 34$). The intervention group completed fraction activities in various Minecraft worlds over seven weeks (duration not reported). The control group received traditional fraction instruction. There was no significant change in the control group from pre-test to post-test ($p = 0.18$), but there was a significant improvement in the intervention group ($p < 0.001$). Finally, Grobelina et al. (2022) examined how Minecraft can be used to help students to learn about Petri nets (mathematical modelling language) in 51 undergraduate students. However, no inferential statistics were reported in the paper. In total, seven studies investigated mathematics outcomes and of those, five reported statistically significant positive effects.

Science-related outcomes

Five studies with medium risk of bias evaluated science-related outcomes (Hobbs et al., 2019; Hobbs, Hartley, et al., 2020; Kersánszki et al., 2023; Li & Wang, 2023; Rader et al., 2021). Four studies used single-group designs (Hobbs et al., 2019; Hobbs, Bentley, et al., 2020; Kersánszki et al., 2023; Rader et al., 2021). Rader et al. (2021) reported improvements in some aspects of geological knowledge following a virtual field camp (four sessions) in Minecraft, which was based on 3D geospatial components of geologic mapping in a sample of 25 university students. Participants completed various activities such as mapping in Minecraft. A number of outcomes of geological knowledge and skill were employed. Some outcomes demonstrated significant improvements though several outcomes did not demonstrate any improvements. In another study, Hobbs, Hartley, et al. (2020) evaluated the impact of a Science Hunters'[1] 'coral reef' session with Minecraft on students' ($N=68$; 9–10 years) knowledge of the topic. Pre- and post-assessments consisted of three questions which were taught during the session. The results indicated a significant improvement in scores from pre- to post-test ($p<0.001$). In a similar study, Hobbs et al. (2019) reported improvements in science knowledge (three questions assessing volcano or habitat knowledge) following an educational science Minecraft-based intervention on volcanoes ($n=269$) or habitats ($n=223$) in children and adolescents (7–14 years). Notably, in this study, significant differences were found between boys and girls at pre-test though these differences were not controlled for in the main analysis. Li and Wang (2023) investigated the application of co-design activities in agricultural education (four workshops) with 30 students aged 9–12 years using Minecraft. The experimental group had higher agricultural literacy scores ($p<0.01$) compared to the control group at post-test. Lastly, Kersánszki et al. (2023) examined the impact of a summer camp that used Minecraft as a tool for helping students ($N=15$) to learn about the topic of renewable energy; however, no inferential statistics were conducted.

Other academic outcomes

Three studies investigated other academic outcomes, vocabulary mastery (Sudarmaji & Yusuf, 2021), writing fluency (Abdalkader, 2023) and economics knowledge (Pirlet, 2021). Sudarmaji and Yusuf (2021) reported significant improvements in class 5 students' vocabulary mastery. In this study, participants were assigned to an intervention group ($n=31$) or a control group ($n=32$). The intervention group completed activities in Minecraft (little to no information is provided on the intervention in the paper). The control group received conventional mastery instruction. At post-test, vocabulary scores were higher in the intervention group when compared to the control group ($p<0.001$). Abdalkader (2023) reported significant improvements in a researcher-developed writing fluency test following 24 sessions in which Minecraft was 'modded' (a type of modification) by AI tools in order to hold discussions with students ($N=33$, mean age = 15 years). Pirlet (2021) investigated an economics DGBL intervention with Minecraft Education in high school students ($N=25$) over nine weeks. The game was modified to incorporate economics concepts like opportunity cost, global trade, and supply and demands. Descriptive improvements in economics knowledge (researcher-developed) from pre-test to post-test were reported; however, no inferential statistics were conducted.

Other outcomes

Six studies with medium risk of bias (Li & Wang, 2023; McColgan et al., 2018; Opmeer et al., 2019; Saricam & Yildirim, 2021; Sun & Li, 2019; Tablatin et al., 2023) examined motivational-affective outcomes. These studies reported improvements in emotional engagement (Opmeer et al., 2019), confidence and skill using technology (McColgan et al., 2018), STEM career interest (Saricam & Yildirim, 2021), STEM interest (Tablatin et al., 2023), interest/enjoyment (Li & Wang, 2023) and creative self-efficacy (Sun & Li, 2019). Opmeer et al. (2019) investigated how a sustainable spatial planning project over 16 weeks in Minecraft impacted students' emotional engagement. Adolescents ($N=101$) were assigned to the intervention group ($n=56$) or a control group ($n=45$). The intervention group was asked to use Minecraft to design a sustainable development of islands. The control group completed the same activity using paper and pencil. At post-test, the control group demonstrated a higher disaffected emotions score (assessed using the Positive and Negative Affect Scale) compared to the intervention group ($p=0.002$). In another study, McColgan et al. (2018) used a single-group design to investigate whether Minecraft, as part of an undergraduate course, had an impact on students' ($N=77$) perceptions of their skills, attitudes and confidence using games for teaching in middle and secondary school classrooms. Students completed a Minecraft project over seven weeks, which involved playing Minecraft, experiencing sample physics lessons, developing their own Minecraft environment, creating assessments, and writing lesson plans. The results indicated there were significant improvements in students' perceptions of their skills using technology ($p=0.003$, $\eta^2=0.16$) and confidence with new technology ($p<0.001$, $\eta^2=0.34$). Tablatin et al. (2023) investigated the impact of What-If Hypothetical implementations in Minecraft on students' STEM interest ($N=117$, 13–14 years). There were no statistically significant changes from pre- to post-test for overall score on the STEM interest questionnaire ($p=0.077$); however, there were significant improvements ($p=0.025$) from pre-test to post-test on the Choice Actions subscale of the questionnaire (perceptions that STEM-related actions will provide support for one's future career). Finally, Kersánszki et al. (2023) included a collaboration skills questionnaire; however, no inferential statistics were reported in the paper.

One study with a medium risk of bias, Samsudin et al. (2022), reported improvements in students' ($N=33$; aged 12 years) 21st century learning skills (assessed using a questionnaire) following a Minecraft Education-based intervention over 10 weeks. During the intervention, students explored, built and recreated worlds/structures based on specific themes (e.g. the topic of sustainability by building a home that used renewable energy). The results indicated that students improved on the outcome measure from pre- to post-test.

Studies with high risk of bias

Five studies had high risk of bias (Checa-Romero & Pascual Gómez, 2018; Craft, 2016; Gadbury & Chad Lane, 2023; Melián Díaz et al., 2020; Zhu & Heun, 2017).

Cognitive outcomes

Two studies with high risk of bias investigated cognitive outcomes (Checa-Romero & Pascual Gómez, 2018; Melián Díaz et al., 2020). These two studies examined the impact of Minecraft on creativity and reported positive effects (Checa-Romero & Pascual Gómez, 2018; Melián Díaz et al., 2020). In a sample of 15 university students, Melián Díaz et al. (2020) reported improvements in creativity (assessed using the Creativity Operation Test) following a two-session intervention, which involved participants drawing objects in 2D and constructing them in 3D in Minecraft (e.g. their dream house). Checa-Romero and Pascual Gómez (2018) also reported statistically significant improvements in creativity (assessed using the CREA Creativity Intelligence Test) from pre- to post-test but in a sample of 85 adolescents aged 12–15 years. In this study, participants completed six sessions focused on building the house of their dreams in Minecraft, and then created a video to demonstrate their builds.

Academic outcomes

One study that investigated academic outcomes had high risk of bias (Craft, 2016). Craft (2016) conducted an action research project as part of a history project with their students (13–18 years). Students built buildings in ancient Rome (e.g. a Roman temple). The study reported descriptive improvements in students' Roman history knowledge (researcher-developed assessment) from pre- to post-test. However, no statistical analyses were performed on the data.

Other outcomes

Two studies with high risk of bias (Gadbury & Chad Lane, 2023; Zhu & Heun, 2017) examined other outcomes. Gadbury and Chad Lane (2023) investigated the extent to which a STEM-related Minecraft summer camp influenced adolescents' STEM interest. The camp revolved around exploring and building in custom build Minecraft worlds that focused on topics like astronomy and earth science. A paired samples *t*-test indicated that there was no change in STEM interest from pre-test to post-test ($p=0.914$). In another single-group study, Zhu and Heun (2017) investigated the use of Minecraft for Chinese history education (three sessions) in 50 adolescents. The researchers recreated the landscape of the Forbidden City, the Chinese imperial palace for the Ming and the Qing dynasties and participants were required to complete various tasks (e.g. collect construction materials and build a palace). The results indicated that motivation for studying Chinese scores significantly increased ($p<0.05$; exact *p* value not reported and no mean/SD values are reported).

DISCUSSION

The popularity and widespread use of Minecraft as a DGBL tool highlights the need to determine the evidence base behind it to ensure any claims about its effectiveness in improving learning outcomes are appropriate. The present study provides a systematic review of Minecraft interventions targeting academic, cognitive, motivational-affective and social outcomes in children, adolescents and young adults. Interventions used both the off-the-shelf version of Minecraft as well as the educational version, although a smaller number employed the latter ($n=8$). Most studies investigated the impact of Minecraft on cognitive and academic outcomes. A very small number of studies examined motivational-affective outcomes. The current evidence indicates that Minecraft is a promising tool to enhance cognitive and academic outcomes; however, all studies had medium or high risk of bias, which must be considered when interpreting any reported effects.

Twenty-four studies included in this review had a medium risk of bias, while five studies had high risk of bias. Studies with medium and especially high risk of bias are more likely to introduce bias into the results. Biases may result in either an underestimation or overestimation of the true effect of an intervention (Boutron et al., 2022). Studies with high risk of bias are considered to represent the lowest form of evidence. The absence of studies with a low risk of bias is particularly notable, as the inclusion of medium and high risk of bias studies reduces confidence in our findings. This review provides insights into the use of Minecraft in educational settings; however, the findings should be interpreted with caution. More rigorous studies are required in the future to determine the true effect of Minecraft as an educational tool. We encourage readers to assess the quality of the evidence of each study by referring to Tables 3 and 4. The first part of this discussion addresses the diverse methodological factors that may introduce bias, followed by an examination of Minecraft's possible applications in different educational settings.

Methodological factors that complicate the interpretation of results

This section summarises these factors and discusses how these issues influence the interpretation of effects. These issues included (1) study designs, (2) statistical analyses and reporting, (3) construct measurement and (4) intervention characteristics. It is our hope that this analysis will advance the evidence base by ensuring more rigorous methods across these areas for any future DGBL interventions with Minecraft.

Twenty-two studies in this review had single-group designs. One major limitation of this type of study design is that confounding variables are not accounted for. For example, some interventions that used single-group designs were often conducted over several weeks (e.g. Checa-Romero & Pascual Gómez, 2018; Kutay & Oner, 2022; McColgan et al., 2018; Pirlet, 2021; Samsudin et al., 2022; Sun & Li, 2019). Note, the intervention duration was not clear in other studies (e.g. Craft, 2016; Koivisto et al., 2019; Rader et al., 2021; Zhu & Heun, 2017). This raises the possibility that any observed improvements in outcomes might have been due to cognitive maturation rather than Minecraft. Thus, across the vast majority of studies the 'true' effect of Minecraft is not clear as the confounding effect of time cannot be excluded (i.e. Minecraft is only one possible explanation for improved scores). Seven studies (out of 29) used a between-subjects design (Carbonell-Carrera et al., 2021; Grobelina et al., 2022; Li & Wang, 2023; Opmeer et al., 2019; Qu et al., 2023; Sudarmaji & Yusuf, 2021; Tangkui & Keong, 2021). This design provides a more rigorous test of an intervention's effect. However, none of these studies randomly assigned participants to groups, which is important to help ensure groups are comparable and reduce the influence of confounding variables on the results. Moreover, many of the included studies had small sample sizes. For instance, nine studies had sample sizes of less than 30 participants. A false positive result is more likely to occur with small sample sizes (Button et al., 2013). Notably, no studies reported conducting an a priori power analysis, in line with best practice, to determine the required sample size to detect a specified effect size. Future research in the field should address these issues.

There were various statistical issues across studies. Some studies failed to adequately examine and account for potential confounding variables (e.g. age, gender) during data analysis. For example, Hobbs, Bentley, et al. (2020) reported improvements on science-related knowledge; however, notably, males and females differed on the dependent variable and this difference was not accounted for in the main analysis. Another statistical issue related to this is the matching of groups in between-subjects study designs, which is important for evaluating intervention effects (Simons et al., 2016). Only one of the five studies that included both an intervention and control group reported the groups were matched on outcome measures at baseline. Notably, no between-groups study reported that groups were matched on sociodemographic variables at baseline. Other statistical issues identified across the studies related to inadequate statistical analyses (e.g. not accounting for clustering in the data; Koivisto et al., 2019) and reporting (e.g. not reporting inferential statistics and group-level descriptive statistics in full; Zhu & Heun, 2017). Consequently, it is difficult to make appropriate inferences about the actual benefits of Minecraft on learning outcomes across these studies.

Many of the outcome measures used in studies were modified versions of existing measures (e.g. Lux, 2019; Zhu & Heun, 2017) or researcher-developed measures (e.g. McCashin et al., 2019; Rader et al., 2021; Sudarmaji & Yusuf, 2021). Often these measures had dubious psychometric properties. For example, studies typically did not provide reliability support (e.g. Aridi & Saad, 2020; Craft, 2016; Koivisto et al., 2019; McCashin et al., 2019; Rader et al., 2021; Sudarmaji & Yusuf, 2021; Tangkui & Keong, 2021; Zhu & Heun, 2017). This was particularly the case for studies that included academic-related outcomes, which is problematic as most measures were original or researcher-developed. In the current review, the studies by Hobbs et al. (2019), Hobbs, Bentley, et al. (2020) and Hobbs, Hartley, et al. (2020), explicitly taught answers to assessment questions (three-multiple choice questions) during the intervention. In DGBL research, standardised outcome measures (e.g. student achievement scores) or other validated measures are preferable to measures developed by the research team for the study, as researcher-developed content can be too closely aligned with the intervention and bias the results (All et al., 2016). While we acknowledge that such measures may fail to capture all the potential learning that may occur in a digital environment, they would provide a more stable foundation for understanding the impact of DGBL with Minecraft.

The nature of the interventions included in this review varied. Abdul Jabbar and Felicia (2015) highlight how the diverse nature of game-based learning interventions can make it difficult to assess the effectiveness of interventions. Some studies included Minecraft as a stand-alone intervention (e.g. McCashin et al., 2019; Zhu & Heun, 2017), while other studies embedded Minecraft into a larger intervention programme (e.g. Hobbs et al., 2019; Hobbs, Hartley, et al., 2020; Rader et al., 2021). When embedded into a larger programme, Minecraft represents only one component among others. For example, Checa-Romero and Pascual Gómez (2018) required students to build the 'house of their dreams' in Minecraft and then create a video detailing their creation. The design of these multiple component interventions does not allow one to establish the impact of each stand-alone component. It is thus very difficult to ascertain what aspect(s) of the programme is driving any observed effects. Another issue identified related to the description of intervention-related activities that participants completed. Often little-to-no information was provided on what participants did (e.g. group vs. individual activities, type of activities), the intervention duration (minutes/hours and time course) and the facilitator/instructor (e.g. Sudarmaji & Yusuf, 2021). Similarly, this lack of information makes it difficult to infer what aspects of DGBL with Minecraft can promote learning.

Using Minecraft within varying learning contexts

This review provides important insights into how Minecraft can be used across learning contexts, particularly insights into fostering learners' spatial reasoning and creativity, and science and mathematics education. This section discusses insights gleaned from included studies on how Minecraft may be used to support learning in these areas.

Two studies investigated the impact of Minecraft on spatial reasoning and reported positive effects (Carbonell-Carrera et al., 2021; Lux, 2019). Minecraft and Minecraft Education likely offers rich opportunities for developing learners' spatial reasoning through play. This is because the core gameplay requires learners to use their spatial skills to build structures, navigate the game's environment and solve problems. For example, Carbonell-Carrera et al. (2021) asked participants to build the house of their dreams in Minecraft and focused on converting between 2D and 3D representations. The finding that the game may help to support the development of spatial skills is notable given the strong association between spatial cognition and STEM educational and occupational outcomes (Wai et al., 2009). Current evidence suggests that spatial instruction in many countries, including the US, is overlooked at primary and secondary level (Gilligan-Lee et al., 2022; Verdine et al., 2014). This highlights the need to support spatial skill development. The findings of this review tentatively support the recommendation that educators can embed Minecraft into their practice to help support students' spatial skills. However, studies that are more robust are needed to further investigate this.

Three studies reported positive effects of Minecraft on creativity (Checa-Romero & Pascual Gómez, 2018; Melián Díaz et al., 2020; Saricam & Yildirim, 2021). Two of these studies (Checa-Romero & Pascual Gómez, 2018; Melián Díaz et al., 2020) required participants to design and build structures within the game. The other study (Saricam & Yildirim, 2021) also included a design and build component, but required participants to find creative solutions to posed STEM problems in Minecraft (e.g. design plant cell models). Interestingly, the Minecraft activities in Checa-Romero and Pascual Gómez (2018) and Melián Díaz et al. (2020) were very similar to the activities employed in Carbonell-Carrera et al. (2021). Several reasons may explain why Minecraft supports creativity. First, the open-ended nature of the game allows educators and learners a high degree of flexibility and autonomy in how they use it, which can help foster the development of creativity (Davies et al., 2013). Second, Minecraft is a blank canvas that stimulates students' imagination and creativity as students must use their imagination to build structures and solve problems using the different materials available (e.g. Slattery et al., 2023). This may offer students more creative possibilities than the physical classroom environment. The findings of this review suggest that Minecraft has the potential to support and develop creativity skills among learners.

Five studies investigated the impact of Minecraft on science-related outcomes. Four of these studies reported statistically significant effects. In these studies, Minecraft was used as a tool (sometimes in combination with other tools) to teach students about scientific concepts, namely ecosystems (Hobbs, Bentley, et al., 2020), habitats (Hobbs et al., 2019), geological features (Hobbs et al., 2019; Rader et al., 2021) and agriculture (Li & Wang, 2023). In these studies, the game's open-ended nature allowed students to explore and experiment with scientific ideas, and its immersive environment provided an opportunity for students to apply scientific concepts and knowledge in a practical and creative way. For example, in Hobbs, Hartley, et al. (2020), participants designed and built their own underwater ecosystems. The findings from these studies suggest that the use of Minecraft in science education may offer a unique and engaging approach for learning scientific concepts and facilitate the practical applications of scientific knowledge.

Seven studies investigated mathematics-related outcomes. Five of these studies reported statistically significant positive effects (Aridi & Saad, 2020; Koivisto et al., 2019; Kutay & Oner, 2022; Qu et al., 2023; Tangkui & Keong, 2021). Aridi and Saad (2020) reported positive effects of Minecraft on students' geometry knowledge though there was limited information on the characteristics of the intervention. As previously mentioned, Minecraft offers rich opportunities for the development of students' spatial reasoning, which is strongly linked with geometry (Clements & Battista, 1992). Educators may use Minecraft to teach geometry via hands-on explorations in a variety of ways including building shapes (e.g. building shapes like pyramids may help students' gain a better understanding of the properties of shapes such as volume, area, angles), measuring (e.g. measuring length, width, height and angles) and visualisation of geometric concepts (e.g. transformations and symmetry). Three studies reported positive effects of Minecraft on computational thinking (Koivisto et al., 2019; Kutay & Oner, 2022; Qu et al., 2023). These studies used Minecraft (Koivisto et al., 2019; Qu et al., 2023) and Minecraft Education (Kutay & Oner, 2022) to teach students coding concepts, and required students to complete coding activities to create within the game. Notably, Minecraft Education has a built-in code builder that educators can specifically use to teach students programming and coding concepts by creating artefacts within the game. Moreover, both versions of the game contain a resource material called Redstone that educators can use to teach students about logic gates, circuits and automation.

Addressing high and medium risk of bias in quantitative DGBL intervention studies with Minecraft

To address the issue of high and medium risk of bias in quantitative studies, the first step is recognising the existence of this issue in the current literature. This systematic review marks a significant contribution to that recognition. However, when conducting experimental research in educational settings, it is important to understand and appreciate the various constraints that researchers face in attempting to minimise bias. Experimental educational research encounters multiple practical challenges such as the random assignment of learners or groups of learners to conditions, the inclusion and appropriateness of control groups and the inclusion of follow-up assessments. Administering interventions in learning environments can be difficult due to their everchanging nature and the complex needs of learners. Teachers face many practical constraints when embedding interventions into their practice, such as time limitations and overloaded curricula. Additionally, it can be difficult to recruit and retain educational partners for longitudinal research. Another issue relates to training researchers in experimental research methods and data analysis. However, these challenges are not exclusive to DGBL intervention studies using Minecraft. The use and appropriateness of experimental research in education has long been debated (e.g. Biesta, 2007), yet numerous robust experimental studies have been successfully conducted in various related areas. For example, one of the largest robust experimental studies to evaluate an educational intervention, the National Study of Learning Mindsets, examined the impact of a brief online intervention designed to improve students' learning by developing a growth mindset in a nationally representative sample of ninth graders from U.S. public schools ($N = 12{,}490$ students attending 65 schools; Yeager et al., 2019). Schools were invited to participate using stratified random sampling. Students were randomised to the intervention or active control condition. To ensure independence of findings, recruitment, randomisation, intervention delivery and data collection, intervention fidelity, and preparation of analysis files were carried out by third-party research consultants. Analysis plans, specifying outcome measures (including GPA) and subgroup effects were pre-registered to enhance transparency. Data analysis accounted for the clustered nature of the data. Although this study does not evaluate a DGBL intervention, it is an example of a rigorous experimental intervention in education.

Since our last literature search at the end of February 2024, our team has published a two-level cluster randomised controlled trial (RCT) examining the impact of a Minecraft Education intervention on spatial thinking in primary school children with a mean age of 11.5 years (SD = 0.58; Slattery et al., 2024). This study involved 32 classes (885 students) randomly assigned for six weeks either to an intervention group or an education-as-usual control group. The sample size was determined using an a priori power analysis. Reliable and valid outcome measures were collected at baseline, post-intervention and at a six-week follow-up. Data analysis accounted for the clustered nature of the data. While the results of the study found no overall intervention-related improvements in spatial thinking, subgroup analyses indicated that class 5 students in the intervention group had significantly higher scores compared to class 5 students in the control. In contrast, there was no significant difference between class 6 students' scores in the intervention and control groups. Importantly, this study implemented open science practices including pre-registration, open data and open coding to maximise transparency. This study serves as evidence that robust experimental research in this field is possible and can act as a methodological model moving forward for future studies.

Other considerations

Qualitative studies were excluded from this review because they do not test the effect of an intervention, which was the primary focus of this research. The aim of this review was to assess the effectiveness of DGBL interventions with Minecraft by measuring their impact on outcomes. This is typically achieved through quantitative methods such as RCTs, quasi-experimental studies and single-group designs. These methods are used to measure the impact of an intervention on specific outcomes, which aligns with the scope of this review. In contrast, qualitative research is focused on exploring individuals' experiences rather than testing casual effects or measuring the effects on an intervention. Qualitative studies provide valuable insights into the processes, context and participant experiences surrounding an intervention (Nastasi & Schensul, 2005); however, they were beyond the scope of this review. We acknowledge that excluding qualitative studies limits our understanding of these factors, which are important for understanding how and why an intervention works. We encourage future research to explore these aspects.

The primary focus of the research reviewed has been whether Minecraft produces effects in the short-term (i.e. immediately after the intervention). While it is essential to establish the presence of short-term effects, it is also important to investigate whether these effects are maintained in the long term. This is because DGBL effects that are not maintained over time have little use or relevance in education (All et al., 2016). In this review, the extent to which any of the reported effects are retained on a long-term basis is unknown, as only one study (Samsudin et al., 2022) included a follow-up assessment. All et al. (2016) recommend a follow-up assessment to occur at least two weeks after the intervention has finished. In our view, this two-week period may be too short. Longer follow-up assessments are needed to demonstrate lasting effects (i.e. one month, two months or three months after the completion of the intervention).

In the age of open science, it is important that DGBL and Minecraft intervention research engage in study preregistration and other open science practices (e.g. open materials and open data). Study pre-registration is particularly important for intervention studies and their evaluation. Pre-registration involves the documentation of a study's hypotheses, research design and data analysis plans prior to beginning a research study. None of the studies included in this review were pre-registered. Pre-registration serves to increase the credibility of a study's results and conclusions, thereby strengthening the evidence it provides. Future Minecraft and DGBL intervention studies should be pre-registered, and implement other open science practices to strengthen the evidence base.

Although this review has several strengths (e.g. focused specifically on Minecraft, broad scope and searching grey literature sources to reduce publication bias), its methodological weaknesses should be acknowledged. First, data extraction was performed by only one reviewer. Best practice standards for conducting systematic reviews advise that more than one reviewer completes data extraction to minimise errors and reduce biases (Boutron et al., 2022). Second, as only English-language publications were included, some relevant publications may have been missed; however, recent research suggests that limiting systematic reviews to only English publications has minimal influence on review results (Dobrescu et al., 2021).

CONCLUSION

In conclusion, digital games do not have the same impact on learning outcomes (Dale & Shawn Green, 2017). We found promising evidence that DGBL with Minecraft can improve cognitive (i.e. creativity, spatial reasoning) and academic (i.e. mathematics and science) outcomes in children, adolescents and young adults. However, the quality of that evidence is limited, which restricts the claims we can currently make about the value of DGBL with Minecraft in improving students' learning outcomes. Moving forward, Minecraft-based DGBL studies should employ more rigorous research methods to determine the true effect of DGBL with Minecraft. It is hoped that this review will support researchers in answering this call to action.

AUTHOR CONTRIBUTIONS

Eadaoin J. Slattery: Conceptualization; methodology; writing – original draft; writing – review and editing; formal analysis; investigation. **Paula Lehane:** Methodology; writing – review and editing; investigation. **Deirdre Butler:** Conceptualization; writing – review and editing; funding acquisition; methodology. **Michael O'Leary:** Conceptualization; methodology;

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This research has been funded by Microsoft Education Ireland. Kevin Marshall is a current employee at Microsoft Ireland.

DATA AVAILABILITY STATEMENT

The data are available on reasonable request to the corresponding author.

ETHICS STATEMENT

Ethical approval was not required to carry out this research as no primary data was collected.

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Endnote

[1] Science Hunters is a project that combines Minecraft with a constructivist pedagogy (Hobbs, Bentley, et al., 2020; Hobbs, Hartley, et al., 2020).

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APPENDIX A

Bibliographic literature search November 2021

Database	Hits
APA PsycINFO	76
ERIC (via EBSCO)	70
ERIC (via ProQuest)	74
Web of Science	317
PubMed	19
Education Research Complete	203
Scopus	463
Cochrane Library	3
Total	1225
Duplicates	316 (EndNote) + 183 (Covidence)
Unique studies to screen	726

Database: APA PsycInfo
Host: EBSCO
Parameters: None
Date: 17/11/21
Searcher: Eadaoin Slattery

Search Strategy:

#	Searches	Results
1	TI (minecraft or minecraftedu or "minecraft education edition")	37
2	AB (minecraft or minecraftedu or "minecraft education edition")	72
3	KW (minecraft or minecraftedu or "minecraft education edition")	30
4	S1 OR S2 OR S3	76

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Database: ERIC
Host: EBSCO
Parameters: No limits
Date: 17/11/21
Searcher: Eadaoin Slattery

Search Strategy:

#	Searches	Results
1	TI (minecraft or minecraftedu or "minecraft education edition")	44
2	AB (minecraft or minecraftedu or "minecraft education edition")	67
3	S1 OR S2	70

———————————————.

Database: ERIC
Host: ProQuest
Parameters: No limits
Date: 17/11/21
Searcher: Eadaoin Slattery

Search Strategy:

———————————————

Database: Web of Science Core Collection
Host: ISI
Parameters: 1945 to present
Date: 17/11/21
Searcher: Eadaoin Slattery

Search Strategy:

#	Searches	Results
1	TI = (minecraft or minecraftedu or "minecraft education edition")	171
2	AB = (minecraft or minecraftedu or "minecraft education edition")	264
3	AK = (minecraft or minecraftedu or "minecraft education edition")	122
4	#1 OR #2 OR 3	317

———————————————

Database: PubMed
Host: National Library of Medicine
Parameters: No limits
Date: 17/11/21
Searcher: Eadaoin Slattery

Search Strategy:

#	Searches	Results
1	minecraft [Title/Abstract]	19
2	minecraftedu [Title/Abstract]	0
3	minecraft education edition [Title/Abstract]	0
4	#1 OR #2 OR 3	19

———————————————

Database: Education Research Complete
Host: EBSCO
Parameters: No limits
Date: 17/11/21
Searcher: Eadaoin Slattery

Search Strategy:

#	Searches	Results
1	TI (minecraft or minecraftedu or "minecraft education edition")	113
2	AB (minecraft or minecraftedu or "minecraft education edition")	174
3	KW (minecraft or minecraftedu or "minecraft education edition")	42
4	S1 OR S2 OR S3	203

———————————————

Database: Scopus
Host: Elsevier
Parameters: No limits
Date: 17/11/21
Searcher: Eadaoin Slattery

Search Strategy:

TITLE-ABS-KEY (minecraft OR minecraftedu OR "minecraft education edition")

———————————————

Database: Cochrane Library
Host: Cochrane Library
Parameters: No limits
Date: 17/11/21
Searcher: Eadaoin Slattery

Search Strategy:

Web searching

Date	Portal/URL	Search terms	Results (checked/included)	Notes
03/12/21	Open Science Framework (OSF) Preprints https://osf.io/preprints/	Minecraft	17/1 1 taken forward to full-text screening – Arini et al. (2023)	17 records screened on title/abstract
03/12/21	Google scholar https://scholar.google.com/	(minecraft) AND (pretest OR posttest) OR (pre-test OR post-test)	50/14 14 taken forward to full-text screening – Amouzadeh et al. (2018), Aridi and Saad (2020), Binti Kasdi et al. (2019), Hipp (2015), Hobbs et al. (2019), Lux (2019), Cifuentes Pabon, (2018), Sirin et al. (2018), Smith and Burd (2019), Sudarmaji and Yusuf (2021), Sun and Li (2019), Tangkui and Keong (2020, 2021) and Zorn et al. (2013)	First 5 pages screened on title/abstract ($N=50$)
06/12/21	Open Grey https://doi.org/10.17026/dans-xtf-47w5	Minecraft	0	

Updated Bibliographic Literature Search December 2022

Database	Hits
APA PsycINFO	10
ERIC (via EBSCO)	–
ERIC (via ProQuest)	3
Web of Science	37
PubMed	4
Education Research Complete	14
Scopus	84
Cochrane Library	1
Total	153
Duplicates	43
Unique studies to screen	110

Database: APA PsycInfo
Host: EBSCO
Parameters: November 2021 to December 2022
Date: 28/12/22
Searcher: Eadaoin Slattery

Search Strategy:

#	Searches	Results
1	TI (minecraft or minecraftedu or "minecraft education edition")	6
2	AB (minecraft or minecraftedu or "minecraft education edition")	10
3	KW (minecraft or minecraftedu or "minecraft education edition")	4
4	S1 OR S2 OR S3	10

——————————————————

Database: ERIC
Host: ProQuest
Parameters: 17/11/21 to 28/12/22
Date: 28/12/22
Searcher: Eadaoin Slattery

Search Strategy:
abstract(minecraft OR minecraftedu OR "minecraft education edition") OR title(minecraft OR minecraftedu OR "minecraft education edition").

Results:
3

——————————————————

Database: Web of Science Core Collection
Host: ISI
Parameters: 17/11/21 to 28/12/22
Date: 28/12/22
Searcher: Eadaoin Slattery

Search Strategy:

#	Searches	Results
1	TI = (minecraft or minecraftedu or "minecraft education edition")	22
2	AB = (minecraft or minecraftedu or "minecraft education edition")	30
3	AK = (minecraft or minecraftedu or "minecraft education edition")	17
4	#1 OR #2 OR 3	37

——————————————————

Database: PubMed
Host: National Library of Medicine
Parameters: 17/11/21 to 28/12/22
Date: 28/12/22
Searcher: Eadaoin Slattery

Search Strategy:

#	Searches	Results
1	Minecraft [Title/Abstract]	22
2	Minecraftedu [Title/Abstract]	0
3	Minecraft education edition [Title/Abstract]	1
4	#1 OR #2 OR 3	4

——————————————

Database: Education Research Complete
Host: EBSCO
Parameters: 01/11/21 to 31/12/22
Date: 28/12/22
Searcher: Eadaoin Slattery

Search strategy:

#	Searches	Results
1	TI (minecraft or minecraftedu or “minecraft education edition”)	9
2	AB (minecraft or minecraftedu or “minecraft education edition”)	13
3	KW (minecraft or minecraftedu or “minecraft education edition”)	5
4	S1 OR S2 OR S3	14

————————————

Database: Scopus
Host: Elsevier
Parameters: 2022 & November–December 2021
Date: 28/12/22
Searcher: Eadaoin Slattery

Search Strategy for 2022:

TITLE-ABS-KEY (minecraft OR minecraftedu OR "minecraft education edition")

Results:
78 records

TITLE-ABS-KEY (minecraft OR minecraftedu OR "minecraft: education edition") AND PUBDATETXT ("November 2021" OR "December 2021")

Search strategy for November–December 2021:

Results:
6 records

——————————————

Database: Cochrane Library
Host: Cochrane Library
Parameters: 17/11/21 to 28/12/22
Date: 28/12/22
Searcher: Eadaoin Slattery

Search Strategy:
(minecraft):ti, ab, kw

Results returned:
1

Updated Bibliographic Literature Search February 2024

Database: APA PsycInfo
Host: EBSCO
Parameters: December 2022 – February 2024
Date: 26/02/24
Searcher: Paula Lehane

Search Strategy:

#	Searches	Results
1	TI (minecraft or minecraftedu or “minecraft education edition”)	5
2	AB (minecraft or minecraftedu or “minecraft education edition”)	13
3	KW (minecraft or minecraftedu or “minecraft education edition”)	5
4	S1 OR S2 OR S3	13

———————————————

Database: ERIC
Host: EBSCO
Parameters: December 2022 – February 2024
Date: 26/02/24
Searcher: Paula Lehane

Search Strategy:

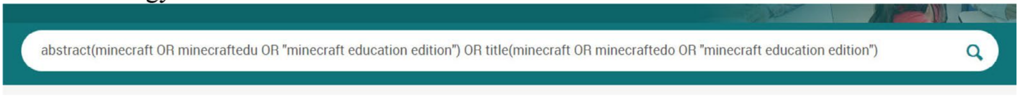
#	Searches	Results
1	TI (minecraft or minecraftedu or “minecraft education edition”)	10
2	AB (minecraft or minecraftedu or “minecraft education edition”)	10
3	S1 OR S2	10

——————————————

Database: ERIC
Host: ProQuest
Parameters: December 2022 – February 202
Date: 26/02/24
Searcher: Paula Lehane

Search Strategy:

Search Strategy:



Results: 6

——————————————————

Database: Web of Science Core Collection
Host: ISI
Parameters: 31-12-2022 to 28-02-2024 (Publication Date)
Date: 26/02/24
Searcher: Paula Lehane

Search Strategy:

#	Searches	Results
1	TI=(minecraft or minecraftedu or “minecraft education edition”)	30
2	AB=(minecraft or minecraftedu or “minecraft education edition”)	48
3	AK=(minecraft or minecraftedu or “minecraft education edition”)	24
4	#1 OR #2 OR #3	51

——————————————————

Database: PubMed
Host: National Library of Medicine
Parameters: 01/12/22–28/02/24
Date: 28/02/24
Searcher: Paula Lehane

Search Strategy:

#	Searches	Results
1	Minecraft [Title/Abstract]	28
2	Minecraftedu [Title/Abstract]	1
3	Minecraft education edition [Title/Abstract]	1
4	#1 OR #2 OR 3	29

Result: 7 hits (with year restriction applied on search #4).

——————————————————

Database: Education Research Complete
Host: EBSCO
Parameters: December 2022 – February 2024
Date: 26/-2/24
Searcher: Paula Lehane

Search Strategy:

#	Searches	Results
1	TI (minecraft or minecraftedu or "minecraft education edition")	14
2	AB (minecraft or minecraftedu or "minecraft education edition")	16
3	KW (minecraft or minecraftedu or "minecraft education edition")	4
4	S1 OR S2 OR S3	23

____

Database: Scopus
Host: Elsevier
Parameters: 2023 to 26/02/24
Date: 26/02/24
Searcher: Paula Lehane

Search Strategy:

TITLE-ABS-KEY (minecraft OR minecraftedu OR "minecraft education edition")

Results:
121 records

____

Database: Cochrane Library
Host: Cochrane Library
Parameters: Dec 2022 to Feb 2024
Date: 26/02/24
Searcher: Paula Lehane

Search Strategy:
(minecraft):ti, ab, kw

Results returned:
2

APPENDIX B

Summary of each study

B.1 | COGNITIVE OUTCOMES

B.1.1. | Carbonell-Carrera et al. (2021)

Carbonell-Carrera et al. (2021) investigated the impact of a Minecraft block-building workshop on students' 3D spatial skills (mental rotation skills). In this study, 34 university students were assigned to an intervention group ($n=17$) or passive control group ($n=17$). The intervention workshop comprised two sessions. The first session provided brief instruction on the operation of the platform. The second session included a training activity (focused on transforming between 2D and 3D representations) and a 'dream house' activity (involved participants building their 'dream house' in Minecraft and drawing this in both 3D and 2D). Both groups completed the Mental Rotation Test at baseline and post-test. Paired sample *t*-tests were conducted comparing pre- and post-test scores in both groups. The intervention group demonstrated significant improvements in mental rotation scores ($p < 0.001$, $d = 0.82$), whereas the control group did not ($p = 0.07$). While the results of this study provide promising evidence for Minecraft as a tool to improve spatial thinking, several limitations restrict conclusions (e.g. small sample size, passive control group, and it is not clear whether the groups are matched at baseline).

B.1.2. | Saricam and Yildirim (2021)

This study investigated the effects of STEM activities in Minecraft Education on class 6 students' ($N = 25$) interest in STEM and scientific creativity. In this single-group study, students completed different STEM activities for 4 h a week over four weeks. The activities required students to create solutions to problems in Minecraft. Outcome measures included STEM career interest and scientific creativity. Participants completed these measures at baseline and post-test. Overall STEM career interest significantly improved from pre- to post-test ($p < 0.05$) in addition to all four subscales (i.e. science, technology, engineering and mathematics; all *p*s reported as $p < 0.05$). In relation to the scientific creativity, there were significant improvements in creativity, authenticity, fluency and flexibility (all *p*s reported < 0.001). While this study reports positive effects, the study employed a single-group design, which does not allows us to make causal inferences.

B.1.3. | Melián Díaz et al. (2020)

Melián Díaz et al. (2020) conducted a study to evaluate the impact of a Minecraft workshop on 3D construction and divergent thinking. In this single-group, university students ($N = 15$; aged 25–35 years) completed two sessions with Minecraft. In the first session (1 h), participants drew a 3D object and constructed the object in Minecraft. In the second session (3 h), participants built the house of their dreams in Minecraft and then drew the house in both 3D and 2D. Participants completed a measure of creativity (Creativity Operation Test) at baseline and post-test. The results indicated that scores (global creativity) significantly improved over time ($p < 0.001$). Limitations include the small sample size, no control group and non-randomised design.

B.1.4. | Lux (2019)

The results of this study are reported across three conference papers (Hughes, Lux, et al., 2020; Hughes, Willoughby, et al., 2020; Lux, 2019). This study evaluated the impact of Minecraft on spatial thinking across two different summer camps in 2018 and 2019. For the purposes of this review, the results from the 2018 summer camp are included here as only preliminary reaction time data from the 2019 summer camp was available at the time of write up. In the 2018 camp (two days), children ($N = 27$) completed activities designed to simulate 3D rotations and train 2D to 3D spatial thinking within Minecraft. The difficulty level increased upon successful completion of each activity. Participants completed two measures focused on (1) mental rotations and (2) 2D to 3D transformations. The results indicated that participants demonstrated statistically significant higher mental rotation scores at post-test compared to pre-test ($p < 0.05$, $d = 0.59$). In contrast, no significant improvements were found for the 2D to 3D transformation test ($p = 0.130$).

B.1.5. | Smith and Burd (2019)

The aim of this single-group study was to examine participants' response activation and inhibition after brief exposure to virtual reality in Minecraft. Twenty-two adults (mean age = 24.59 years, SD = 5.05) completed a virtual reality task in Minecraft, which required them to build a house. Response activation and inhibition were measured using a go/no-go task before and after the task. The results indicated no significant improvements in outcome variables.

B.1.6. | Sun and Li (2019)

The study aimed to examine the impact of an intervention designed to increase students' programming skills. Twenty children (class 7) completed the intervention over 12 weeks. Students used Python in Minecraft to complete various tasks (e.g. to build a house). Minecraft was used in combination with other materials and activities throughout the intervention period. Participants completed measures of creative self-efficacy, critical thinking and attitude towards learning programming at baseline and post-test. Results were analysed using a series of paired sample *t*-tests. Significant improvements in all three measures were found. Strengths include the use of reliable outcome measures. Limitations include incomplete reporting of key demographics (gender), small sample size and single-group design.

B.1.7. | Checa-Romero and Pascual Gómez (2018)

This study investigated the impact of a workshop that involved the use of Minecraft on participants' creativity. In the first phase of this study, 85 adolescents aged 12–15 years (55% boys) completed six workshop sessions focused on building the house of their dreams in Minecraft. In the second phase, participants created a video in which they detailed their creations. Participants completed the CREA Creativity Intelligence Test at baseline and post-test. The results indicated statistically significant improvements in creativity ($p < 0.05$, $d = 0.45$). While this study had a large sample size, the single-group design limits conclusions. Further limitations include: (1) no group level descriptive statistics were reported for the outcome variable, (2) lack of clarity around what outcome variable was used in the analysis and (3) the impact of key sociodemographic variables (age and gender) on the outcome of interest were not examined.

B.2 | ACADEMIC OUTCOMES

B.2.1. | Abdalkader (2023)

This study designed and evaluated a programme using AI applications to improve English as a Foreign Language (EFL) students' writing fluency and self-regulation. The programme included 24 sessions (3 × 2 h sessions per week). For the activities, Minecraft was 'modded' by AI tools (i.e. Grammarly AI app) to hold discussions and pose questions to students. The study employed a single-group pre-test post-test design with a qualitative component. Thirty-three students aged 15 years studying English for 11 years and who had an intermediate level took part. A writing fluency test (researcher-developed) and an EFL students' self-regulation scale (researcher-developed) was administered at pre- and post-test. The writing fluency test had five components: mechanics, organisation, writing smoothness, detecting information, and interpretations and reflection. The self-regulation scale had three components: orientation, performance and evaluation. A series of paired samples *t*-tests were conducted to examine the impact of the programme on the outcomes. There was a significant improvement from pre-test to post-test for overall writing fluency ($p < 0.001$; eta squared = 0.77). Participants demonstrated significant improvements across all five components of writing fluency (all ps < 0.006, eta squared range = 0.539–0.699).

There was a significant improvement in students' overall self-regulation skills ($p < 0.001$, eta squared = 0.947) and each of the three subcomponents (all ps < 0.005, eta squared = 0.899 to 0.877).

B.2.2. | Grobelina et al. (2022)

This study examined how Minecraft can be used to help students learn Petri nets (a type of mathematical modelling language). Fifty-one male students (average age = 20 years) were allocated to an experimental ($n = 43$) and control group ($n = 8$) with pre- and post-assessments. Assessments comprised 15 single-choice questions focused on the theory and application of Petri nets. The control group completed the assessment at post-test only (no further information on the assessments is reported). The intervention comprised two phases. In the first phase, students were taught to integrate Petri nets with Minecraft for simulating physical systems, then they applied this individually or in groups for 90 min. Students were asked to independently experiment with more detailed and complex setups over a week. In the second phase, students were introduced to using Petri nets with Minecraft to simulate machinery, then applied this individually or in groups for 90 min. The control group received traditional lessons. The results are reported descriptively; no statistical analyses were performed. The average score in the experimental group at pre-test was 7.86 (median = 7) and post-test was 12.02 (median = 12). The average score in the control group at post-test was 11.13 (median = 11).

B.2.3. | Li and Wang (2023)

This study investigated the application of co-design activities in an agricultural education class using Minecraft. A mixed methods quasi-experimental non-equivalent control group design was used. Thirty Chinese students aged 9–12 years participated. In the experimental group ($n = 15$) four workshops were held. The aim was for students to build a scaled-down agricultural landscape in Minecraft based on local geomorphic features. Students were provided with a preliminary session on agriculture, introduced to Minecraft, researched local terrains and shared their knowledge. They then built their ideas on paper, built their prototype in Minecraft and shared their construction using screencast. The control group ($n = 15$) received their traditional agricultural teaching (no further information is provided). Agricultural literacy was assessed using a scale comprised of a 12-item MCQ agricultural knowledge and an additional 10 items relating to agricultural attitude at pre-test and post-test (no psychometric information provided). Enjoyment/engagement was also measured using a 15-item scale (no psychometric information provided). The quantitative outcome data was analysed using an ANCOVA, controlling for pre-test scores. The paper reports that the experimental group had higher agricultural literacy ($p < 0.01$) and enjoyment/engagement ($p < 0.001$) compared to the control group at post-test.

B.2.4. | Kersánszki et al. (2023)

This study examined the impact of a summer camp that used Minecraft as a tool for helping students to learn about the topic of renewable energy. There were 15 participants (10–16 years, 14 boys, mean age = 11.6 years). Assessments of their knowledge (10-item MCQ questionnaire) and collaboration skills (assessed using the collaborative skills questionnaire) were administered before and after the camp. During the camp, participants designed, built and explored power plants/energy sources. No inferential statistics were carried out. Descriptive statistics were reported. The paper reported that the percentage of correct answers improved from 47.33% at pre-test to 60.67% at post-test. The paper also reported that collaboration skills improved with higher average scores reported at post-test than at pre-test.

B.2.5. | Qu et al. (2023)

Qu et al. (2023) examined the impact of a Python lesson using Minecraft on students' computational thinking skills using a mixed-methods design (between-subjects design with student interviews). Computational skills were measured using an adapted version of the self-report computational thinking scale (CTS; Korkmaz et al., 2017). The scale measures 5 dimensions of computational thinking: creativity, problem-solving, algorithmic thinking, cooperation and critical thinking. Sixty first-year high school students participated in the study. Students were assigned to an experimental ($n = 30$) or control group ($n = 30$). The lesson involved students using Python code to complete actions in Minecraft. The CTS was administered at pre-test and post-test. At post-test, the results indicated that the experimental group had significantly higher scores on all five dimensions relative to the control (all ps < 0.041), suggesting that the lesson improved students' computational thinking skills. It is unclear whether a true experimental design was employed. The paper states that participants were randomly assigned to groups; however, the study is described as a quasi-experimental design. A strength of this study was that groups were matched on outcome measures at baseline.

B.2.6. | Kutay and Oner (2022)

Kutay and Oner (2022) investigated the impact of a Minecraft Education-based coding intervention on class 5 students' ($N = 20$) computational thinking skills. The study used a single-group pre-test post-test design. The outcome measure was knowledge of computational concepts assessed using a computational learning test with Scratch (pre-test) and a computational learning test with Minecraft Education (post-test). Students completed the intervention for 6 weeks (1 h per week). A coding curriculum was designed based on adapting activities from the Minecraft Education MakeCode curriculum. Each week students were introduced to new coding concepts (e.g. loops) and completed related activities in the platform. The intervention culminated in a final project that required students to complete multiple coding tasks. The results indicated that knowledge scores significantly improved from pre-test (M = 3.55, SD = 2.87) to post-test (M = 12.9, SD = 5.98; $p < 0.01$; $r = 0.87$).

B.2.7. | Pirlet (2021)

This study investigated an economics DGBL intervention with Minecraft Education in high school students ($N = 25$; class 10–12). The study primarily used qualitative methodology; however, assessments of economics knowledge (developed for the study) were administered at pre-test and post-test. Students completed 18 h of gameplay (24 sessions) over nine weeks. The game was modified to incorporate economic concepts like opportunity cost, global trade and supply and demand. Examples of modifications included resource specialisation, pre-determined land plots, movement restrictions and a central trading area. Individual pre-test/post-test scores were presented for each student (i.e. no group level descriptive statistics or inferential statistics were reported). We calculated group level statistics and the mean score increased from pre-test (M = 13.12, SD = 3.05) to post-test (M = 19, SD = 3.18).

B.2.8. | Rader et al. (2021)

This study developed a virtual course in Minecraft, which represented the 3D geospatial components of geologic mapping typically completed in person. Undergraduate students ($N = 25$) completed four virial field camp sessions in Minecraft. The first session reviewed concepts learned in previous courses. The second session looked at orienting in the game and students undertook a mapping exercise. The third session required students to use Minecraft together with other applications and tasks to replicate the experiences of geoscientists. The final session required students to apply all their skills in a Minecraft mapping world. Geological knowledge/skill was the outcome of interest; however, the precise outcome variables are not clear. A nonparametric Wilcoxon Signed-Rank test was used to compare differences in outcome measures from pre- to post-test. Some outcomes from the geological knowledge and skills assessments demonstrated significant improvements though a number did not demonstrate any improvements. Limitations include the small sample, single-group design and construct measurement (outcomes not clear, no reliability reported).

B.2.9. | Sudarmaji and Yusuf (2021)

The aim of this study was to investigate whether an educational Minecraft intervention had an impact on students' vocabulary mastery. Children (class 5) were assigned to an intervention group ($n=31$) or education-as-usual control ($n=32$). A vocabulary mastery assessment (20 questions measuring four vocabulary mastery indicators – meaning, writing, usage and pronunciation) was administered at baseline and post-test. The paper reports that before the pre-test a 'validation of the test was employed' but no further information is provided in the paper and no reliability statistics are reported. The paper reports little-to-no information on the intervention. The control group was taught vocabulary using traditional methods (no further detail provided). An independent samples *t*-test was used to compare the intervention and control group at post-test and indicated that vocabulary scores were higher in the intervention group ($p<0.001$). Limitations include the non-randomised design, construct measurement issues, inadequate intervention description and inadequate statistical analysis/reporting.

B.2.10. | Tangkui and Keong (2021)

The purpose of this study was to investigate the impact of Minecraft on students' achievement in fractions. Sixty-five students (class 5) were assigned to the intervention group ($n=31$) or an education-as-usual control ($n=34$). The intervention group completed various fraction problem-solving activities in different Minecraft worlds over 7 weeks. The control group received traditional instruction. A researcher-developed 15-item assessment of students' fraction problem-solving abilities was administered at baseline and post-test. Paired sample *t*-tests were used to compare change in both the intervention and control group over time. There was no significant change in the control group ($p=0.18$), but there was a significant improvement in the intervention group ($p<0.001$). Independent samples *t*-tests were also conducted on post-test scores and these indicated that scores in the intervention group were significantly higher than the control group. While this study included a control group, there is no information on whether the groups were matched at baseline. This is important as assignment to groups was not random. Note, the results of this study are also reported in Tangkui and Keong (2023). In this paper, assessment items are grouped into three categories that assess various aspects of 'higher-order thinking' in fraction problem-solving skills, namely analysing, evaluating and creating. A series of paired samples *t*-tests were used to analyse the results. There was no significant difference between pre-test and post-test scores in the control; however, there were significant improvements from pre- to post-test in the experimental group across all three outcomes (all $ps<0.001$). Additionally, the experimental group had significantly higher scores at post-test, relative to the control group on all outcomes (all $ps<0.03$).

B.2.11. | Aridi and Saad (2020)

This study examined the impact of MinecraftEdu on geometry knowledge. In this single-group study, children ($N=10$; aged 9–11 years) took part in Minecraft sessions over three weeks. The teacher introduced the game (how to navigate and build) and students completed tasks (not clear what tasks were involved). Students completed assessments of geometry knowledge before and after the intervention (no reliability reported). The paper reports that scores were significantly higher at post-test compared to pre-test ($p<0.001$). However, due to the type of design (single-group) and small sample size employed, caution is warranted in interpreting the results.

B.2.12. | Hobbs et al. (2020)

Hobbs, Bentley et al. (2020) and Hobbs, Hartley et al. (2020) evaluated the impact of a Science Hunters 'coral reefs' session in Minecraft on children's knowledge of the topic. In this single-group study, 68 children (9–10 years) were introduced to corals and threats posed to coral reefs. They were then able to explore a coral reef and these threats in Minecraft or construct their own coral reef (duration of session and who conducted the session are not reported). Three multiple choice questions were used to assess coral reef knowledge. The answers to these questions were explicitly taught during the session. Data were analysed with a paired samples *t*-test. Before the session, the mean score on these questions was 32% ± 2.9%. After the session, the mean score was 79% ± 3.0%. This improvement was statistically significant ($p < 0.001$). Key limitations include the single-group design and construct measurement issues.

B.2.13. | Hobbs et al. (2019)

This study aimed to evaluate an educational intervention (Minecraft in conjunction with interactive discussion and demonstrations) to engage children with research and science learning. Four hundred and ninety-two children (7–14 years) from 32 schools (both primary and secondary schools) took part in this project. The majority of children had special educational needs (specific disorders/conditions are not reported). Intervention sessions comprised two topics: volcanoes and habitats (see Table 2 for description). Assessments at pre- and post-test comprised three questions on the topic (no information on reliability). The answers were taught during the sessions. Mann–Whitney *U* tests were conducted to examine whether student demographics influenced pre- or post-test scores. For the volcano knowledge assessment, there was a significant difference between the scores of girls and boys at pre-test ($p < 0.05$); however, this was not accounted for in the main analysis, which is problematic as differences between boys and girls could drive any reported effects. The results indicated that scores on the volcano assessment improved from pre- to post-test ($p < 0.001$). For the habitat assessment, there was also a significant improvement in scores from pre- to post-test ($p < 0.001$). Key limitations include not accounting for differences between males and females (volcano assessment), as well as clustering in the data, construct measurement and the single-group design.

B.2.14. | Koivisto et al. (2019)

Koivisto et al. (2019) examined how Minecraft promoted computational thinking in the context of an after-school K-12 programming club. Sixty-two children (7–12 years) were enrolled in five (8–20 participants per club) after-school programming clubs for three months (first four sessions were on Minecraft). The groups used the Earth 2.0 Minecraft world and participants were required to programme robots for reconstructing the earth over four sessions. Participants completed pre- and post-assessments of programming knowledge. Results indicated that programming scores significantly improved ($p < 0.001$) for the whole group from baseline to post-test (paired samples *t*-test). Paired sample *t*-tests are also reported for various subgroups (e.g. children aged 7–9). Limitations include the single-group design, statistical analysis (not accounting for clustered data) and construct measurement (no reliability reported).

B.2.15. | McCashin et al. (2019)

This study investigated whether Minecraft improved participants' understanding of spatial geometry (perimeter, area and volume). Seventy-seven children (9–11 years) from four different computing science summer camps participated. Camps lasted one week and were focused on Minecraft building activities. Participants played in a traditional Minecraft setting, created their own game worlds within Minecraft, and then worked through a Minecraft mathematics intervention activity (integrated perimeter, area and volume). The outcome measure assessed perimeter, area and volume. Test items were designed by an expert in the elementary math curriculum. A paired sample *t*-test indicated that there was no significant difference between pre-test (M = 3.82, SD = 2.86) and post-test (M = 4.29, SD = 2.75) mathematics scores ($p = 0.537$).

B.2.16. | Craft (2016)

This action research study formed part of students' history and foreign language classes. In the first iteration of the project, students (13–18 years) assumed the persona of an architect in ancient Rome, selected a building, researched it and recreated the building in its original Roman location using Minecraft. In the second iteration, the building was provided to students, which eliminated the research element. At baseline and post-test, students completed a written assessment of their knowledge of Roman temples (not clear if this was the same assessment, not clear if students completed the pre-assessment before the first iteration or the second iteration, no psychometric information provided). The results are reported descriptively; no statistical analyses were performed. The mean score of the pre-assessment was 13% (no SD reported) and the mean score of the post-assessment was 60% (no SD reported). This study had several methodological limitations (single-group design, unclear reporting, construct measurement and no inferential statistical analysis) which restricts any conclusions.

B.3 | MOTIVATIONAL, AFFECTIVE AND OTHER OUTCOMES

B.3.1. | Samsudin et al. (2022)

This single-group study investigated the impact of Minecraft on students' 21st century learning skills. Thirty-three students aged 12 years completed Minecraft sessions over 10 weeks. During the sessions, students built and recreated worlds based on specific themes (e.g. sustainability). The outcome measure was students' 21st century learning which was assessed using the 21st century skill questionnaire (adapted). Notably, this study included a two-week follow-up assessment. The results indicated that students improved from pre- to post-test. The paper also notes a significant change in scores from post-test to follow-up; however, the reported p value is not statistically significant at $p < 0.05$ (reported p value = 0.955).

B.3.2. | Opmeer et al. (2019)

This study investigated how a sustainable spatial planning project in Minecraft impacted children's emotional engagement. Adolescents ($N = 101$; aged 12–15 years) were assigned to the intervention group ($n = 56$; two class groups) or the education-as-usual control group ($n = 45$; two class groups). The intervention group was asked to use Minecraft to design sustainable islands. The children in the control group did the same activity using paper and pencil. The project lasted 16 weeks and included research (information to develop a sustainable spatial design) and design. The Positive and Negative Affect Scale (PANAS) questionnaire, a measure of disaffected emotions, was administered before and after the design of the islands. The groups were matched on the outcome measure at baseline. A *t*-test was conducted on post-tests scores. At post-test, the control group demonstrated a higher PANAS score (disaffected emotions) score compared to the intervention group ($p = 0.002$). The paper concluded that Minecraft 'successfully mitigates the development of disaffected emotions during a long-term project based on sustainable spatial planning' (p. 157). Limitations include the use of a non-randomised design. Given the non-randomised design, it is important to examine whether groups are matched on sociodemographic variables at baseline.

B.3.3. | McColgan et al. (2018)

This study investigated whether Minecraft as part of an undergraduate course in education had an impact on students' perceptions of their skills, attitudes and confidence using games for teaching in middle and secondary school classrooms. Students ($N=55$) completed a Minecraft project over seven weeks. The project involved playing Minecraft, experiencing sample physics lessons and developing their own Minecraft environment, creating assessments and writing lesson plans. Students completed assessments of perception of technological skill and confidence teaching with technology at pre- and post-test. The results were analysed using Factorial ANOVAs with one within-subjects factor (time) and one between-subjects factor (gender). It is not clear why gender was included as a between-subjects factor. The main effect of time was statistically significant on perceptions of skill using technology ($p=0.003$, $\eta2=0.16$) and confidence with new technology ($p<0.001$, $\eta2=0.34$). There was no main effect of gender or no gender by time interaction effect on either outcome. The key limitation relates to the use of a single-group design.

B.3.4. | Zhu and Heun (2017)

This study aimed to investigate the use of Minecraft for Chinese history education. Fifty adolescents (mean age = 13.4, SD = 1.2) participated in three sessions. The researchers recreated the landscape of the Forbidden City, the Chinese imperial palace for the Ming and the Qing dynasties and participants were required to complete various tasks. Motivation for studying Chinese (adapted from the Intrinsic Motivation Inventory for Adults) was administered at baseline and post-test. The paper reports that a one-way ANOVA was conducted to compare students' motivation for studying Chinese before and after the Minecraft sessions. The results indicated that motivation scores significantly increased ($p<0.05$; exact p value not reported and no mean/SD values are reported). Limitations include construct measurement issues (no reliability reported) and the single-group design.

B.3.5. | Gadbury and Chad Lane (2023)

This study investigated the extent to which a STEM-related Minecraft summer camp influenced adolescents' STEM interest. Adolescents ($N=96$, 32% female) 11–15 years participated in a week-long summer camp (five 3 h meetings). The camp revolved around exploring and building in custom built Minecraft worlds that focused on topics like astronomy and earth science in the game and included ‘What if’ questions. Participants completed a 20-item STEM interest questionnaire (validated by the research team but no psychometric information is included in the paper) at pre-test and post-test. A paired samples *t*-test indicated no change in STEM interest from pre-test to post-test ($p=0.914$).

B.3.6. | Tablatin et al. (2023)

This study investigated the impact of What-If hypothetical implementations in Minecraft on students' STEM interest using a mixed-methods design. What-If hypothetical implementations in Minecraft are a set of Minecraft worlds (e.g. ‘Rocket Launch from Earth’ world, which is modelled after NASA) which educators can use to support STEM learning. Learners examine these worlds and make observations during their exploration. One hundred and seventeen middle school students (53 male) from the Philippines participated in the study (13–14 years). An adapted version of the 10-item STEM interest (Roller et al., 2018) questionnaire was administered at pre-test and post-test. The questionnaire assesses five constructs (self-efficacy, outcome expectations, interests, choice goals and choice actions). A paired sample *t*-test was conducted to examine changes in STEM interest (overall score) from pre- to post-test. There were no statistically significant changes from pre- to post-test for the overall score on the STEM interest questionnaire ($p=0.077$). Paired samples *t*-tests were also conducted on the five constructs/subscales. There was a significant difference

($p=0.025$) between the pre- (M = 3.34, SD = 1.13) and post-scores (M = 3.5, SD = 1) on Choice Actions (perceptions that STEM-related actions will provide support for one's future career). Additional analyses were conducted to examine changes in scores for low and high performers. For low performers, there was a significant increase in STEM self-efficacy scores from pre- to post-test ($p=0.038$), while for high performers scores on the STEM interest subscale increased from pre- to post-test ($p=0.041$).