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Systematic Review

Non-Digital Games That Promote Mathematical Learning in Primary Years Students: A Systematic Review

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Abstract: Despite primary school teachers demonstrating strong preferences for using non-digital games over digital games to support mathematics instruction, much of the research review literature has focused on learning outcomes associated with digital mathematical games. To address this gap, the current systematic literature review focuses on non-digital, games-based, empirical studies in the primary mathematics classroom over the past two decades from 2003 to 2022. The Preferred Reporting Items for Systematic Reviews (PRISMA) statement was employed as a guideline for the data-collection process. The review presents an analysis and synthesis of 34 manuscripts, representing 32 distinct studies. Over three-quarters of manuscripts employed quantitative methodologies and around half qualitative methodologies, whilst studies focused exclusively on student, as opposed to teacher, outcomes. Despite Australia and Indonesia being comparatively overrepresented, the studies in scope were notable for both their geographic diversity and the eclectic range of game types and structures incorporated; although they did tend to disproportionately focus on number and operations, as opposed to other mathematical content areas. Moreover, the impact of mathematical games was generally positive across the broad range of outcomes considered, suggesting that mathematical games are potentially effective for both developing mathematical proficiencies, as well as improving dispositions towards mathematics. Future research directions are discussed.

Keywords: systematic review; mathematical games; non-digital games; mathematics education; primary education

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1. Introduction

Games are an activity that are frequently employed in mathematics classrooms, particularly within primary schools. For example, more than three-quarters of Australian primary school teachers have reported playing mathematical games multiple times per week to support mathematics instruction [1,2]. The breadth with which games are used by primary school teachers suggests that it is believed that there are tangible benefits associated with students playing mathematical games. Indeed, teachers have reported that games are useful for: engaging students in mathematics lessons; maximizing on-task behavior; generating rich mathematical discussions; differentiating different performance levels; focusing student attention on important mathematical ideas; and developing mathematical proficiencies, that is, procedural fluency, conceptual understanding, problem solving skills, and mathematical reasoning [1]. Moreover, most mathematical games primary teachers choose to utilize involve simple materials (e.g., dice, playing cards, pen and paper) and do not incorporate digital technology. In fact, when asked about their favorite mathematical game for use in a primary classroom, only 1% of teachers chose a digital game or application, and only 4% of teachers chose a game that connected with digital technology in any capacity (e.g., calculators, random number generators, interactive number charts) [1]. This finding has been confirmed by recent research indicating that primary educators are between three and five times more likely to use a non-digital mathematical game than a digital mathematical game in a mathematics lesson, and between 10 and 14 times more likely to state that they prefer using non-digital games compared with digital games [3]. This sustained relevance of non-digital games to support primary mathematics instruction is particularly noteworthy given the ubiquity of digital technology across all facets of life and most aspects of education.

Despite the prevalence of, and teachers' preference for using, non-digital games, much of the research into students and young children playing mathematical games has focused on digital games. This is particularly the case when it comes to research reviews, including systematic literature reviews. For example, Abdul Jabbar and Felicia [4] in their systematic review focused on the educational outcomes associated with game-based learning (i.e., going beyond mathematics) identified 91 studies that met their inclusion criteria, 18 papers related specifically to mathematics learning. Despite the fact that the scope of their review was intended to incorporate both digital and non-digital games, they only managed to identify one study that involved a non-digital game (a board and card game). Likewise, other reviews focused on game-based learning in mathematics specifically have tended to explicitly focus on digital games, rather than non-digital games [5,6], or did not distinguish between game modality [7,8]. Consequently, given the contrast between the frequency with which teachers use non-digital games with students vis-a-vis the tendency to focus on digital games in the review literature, there is a need to undertake a systematic literature review focused on non-digital mathematical games in particular, to help bridge the divide between practice and research.

The review is organized in the following manner. The background offers a definition of games and puts forward the questions this review will address. The methodology section outlines the process for conducting the systematic review, encompassing data selection and the methodological steps taken to analyze the selected papers. The results and discussion section showcases the findings, categorizations, and outcomes analysis, and provides a summary of the evidence. The conclusion presents the limitations of the review and identified research gaps with recommendations for future studies.

2. Background

An extensive desktop scoping search was conducted to establish whether a systematic literature review on non-digital/traditional games for mathematics learning was warranted. As noted previously, our search returned only systematic literature reviews that reported on technological games or computer-based and online games to enhance mathematics learning or that did not distinguish between game modality [5–8]. We were unable to locate any systematic review with a focus on non-digital games in the mathematics classroom or home environment. Considering the results of our scoping search, this systematic literature review is warranted as (a) it provides an overview of the most recent best-practice evidence on non-digital games utilized for mathematics learning, (b) ensures the thorough and consistent use of scientific systematic review methods, and (c) provides an appraisal of the methodological quality of the included studies.

2.1. Research Questions

RQ1. What are the characteristics of the included studies on non-digital mathematical games in primary school settings?
RQ2. How does playing non-digital games impact student and/or teacher outcomes in primary school settings?
RQ3. What is the methodological quality of the included studies?

2.2. Definition of Non-Digital Mathematical Games

Games have a long and rich history of entertaining humans over several millennia. Games are associated with fun, engagement, and entertainment. The word 'game' is often used in an educational setting to describe an activity that might be viewed as enjoyable or to evoke a sense of excitement in the upcoming task, thereby enhancing the likelihood of student participation [9]. Using games in the mathematics classroom needs to be distinguished from the notion of educational gamification, which refers to the process of incorporating game mechanics and game design techniques into educational settings to modify student motivations and behavior [10]. Whereas a mathematical game refers to a discrete activity with specific mathematical learning objectives, gamification effectively involves transforming the mathematics classroom into the game space.

The word 'game' has been liberally employed in the mathematics classroom to include puzzles (e.g., tangrams and jigsaws), competitive drill and practice tasks (e.g., times tables challenges), and luck races (e.g., traditional bingo and snakes and ladders). These examples are effectively activities that have been transformed into 'pseudo-games' [11]. However, these activities would not necessarily meet the definition of mathematical games as defined in the literature. For example, Gough [11] argued persuasively that a 'luck race' does not warrant being defined as a mathematical game, because it involves no player choice and therefore no strategy or skill. Consequently, through synthesizing earlier definitions of games [11–15], we define a mathematical game as an activity that:

- has specific mathematical cognitive objectives;
- requires students to use mathematical knowledge to win the game;
- is enjoyable and with potential to engage students;
- is governed by a definite set of rules and has a clear underlying structure;
- involves a challenge against either a task or an opponent(s) and interactivity between opponents;
- includes elements of knowledge, skills, strategy, and/or luck, but not luck alone;
- has a distinct finishing point.

Building on this definition of a mathematical game, a non-digital game does not employ a digital device or tool to support the playing of the game. Board, dice, and card games are examples of non-digital games. Commercial games, such as Othello, and Go, employed in McFeetors and Palfy's [15] study, are examples of games that fit within the definition of a non-digital mathematical game, particularly given the requirement for logical reasoning and strategic thinking.

Rather than use the above definition of games as an inclusion criterion for our review, we instead chose to report on it as an outcome; that is, to examine whether selected studies incorporated games that could identifiably meet this definition (see Section 4.1.5). Consequently, we extended the parameters of the inclusion criteria for our review to include papers where the authors self-described the activity as a 'game', in order to capture the breadth of research focusing on non-digital mathematical games. Thus, activities that Gough would have described as 'pseudo games' are included in this review. For example, Casey et al.'s [16] 'game' involved a mother and child each drawing three cards from a deck and calculating who has the highest sum to determine the winner of the round. This activity is made game-like through the use of cards and competing against an opponent, yet there is no player choice as the outcome is based on luck alone.

3. Methods

Before commencing the review, a research protocol was established, circulated among all authors, and discussed until consensus was achieved. The systematic literature review process was guided by the Cochrane Handbook for Systematic Review Guidelines and Reporting [17], spanning from August 2022 to July 2023. The following paragraphs outline the process in more detail.

3.1. Inclusion Criteria

We included peer-reviewed journal articles, conference papers, and book chapters in our searches that focused on non-digital games for mathematics learning, published between 2003 and 2022, in the English language. We considered studies on children aged 5–13, which can usually be found in kindergarten (e.g., U.S.), foundation/prep classroom (e.g., Australia), primary school, and middle school (up to Grade 8), and their teachers. The type of publications we intended to include were educational trials, program/intervention evaluations, case studies, and research reports that described student and teacher outcomes. The student outcomes we hoped to find included but were not limited to student experiences, the quality of teacher–student interactions and mathematical discussion in the classroom, enjoyment, academic achievements, cognitive and behavioral changes, changes in the levels of mathematics anxiety, competence, motivation, confidence, engagement, and resilience. Expected teacher outcomes included but were not limited to the quality of teacher–student interactions, levels of confidence, anxiety, enjoyment, agency, efficacy, attitudes towards teaching mathematics, mathematical conceptual knowledge and proficiency, and accounts of their experiences.

3.2. Exclusion Criteria

Publications in a language other than English, those published prior to 2003, studies that had a focus on populations other than those described in our inclusion criteria, and studies with a sole focus on digital, computer-based, and/ or online games were excluded. We excluded theoretical and descriptive papers due to the absence of data and real-world outcomes, protocols, non-peer reviewed conference papers, opinion pieces, news articles, informal reporting on the use of games (e.g., blogs), and papers on game design.

3.3. Search Strategy

The population, intervention, comparison, and outcomes (PICO) tool, as discussed by Methley et al. [18], was utilized to establish and organize the main concepts underpinning the research questions, and together with an expert librarian in the field of education, a sound search strategy was established. The sources for the national and international peer-reviewed literature included: Academic One File, EBSCO (Humanities and Social Sciences Index, Education Index), Emerald Insight, ERIC (ProQuest), Education Database (ProQuest), A+ Education (Informit), PsycInfo (Ovid), SAGE, ScienceDirect (Elsevier), Scopus, SpringerLink, Web of Science, and Google Scholar. To complete the exploration, a manual search of reference lists of the relevant literature was performed. The search strings consisted of the following terms in varying combinations and were tailored to the specific requirements of individual databases/ search engines.

Search string combined with AND: mathematical game OR mathematical games OR mathematics game OR mathematics games; non-digital OR traditional; board OR card OR strategic OR logical OR verbal; primary school OR elementary school OR primary OR elementary; student* OR teacher*

Search string combined with NOT to all or parts of the above: digital OR virtual OR virtual world OR mobile OR software OR computer* OR technol* OR console* OR preschool OR pre-school OR kindergarten OR prep*

3.4. Data Management

One author performed all searches and exported the results into the referencing management software program EndNote X9, v. 21. Duplicates, and any papers published before 2003, were removed. All steps of this process were documented in an Excel spreadsheet to ensure transparency and replicability. Once this process was completed, all items were exported into SysRev, a web-based data curation platform [19], to begin the collaborative process of screening.

3.5. Study Selection

The process used for the study selection is detailed in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA] flow diagram (Figure 1) [20]. The same author who undertook all searches carried out the first step of the study selection process, which comprised the screening of titles, and if necessary, abstracts, to determine relevance. The remaining papers were divided among the four authors. A detailed inclusion/exclusion manual was developed to guide the second step of the screening process. Each item was independently screened by two different reviewers to determine eligibility against the inclusion criteria. Any conflicts were resolved through discussion amongst the authors until consensus was achieved. In a small number of cases, a third author was consulted to arbitrate.

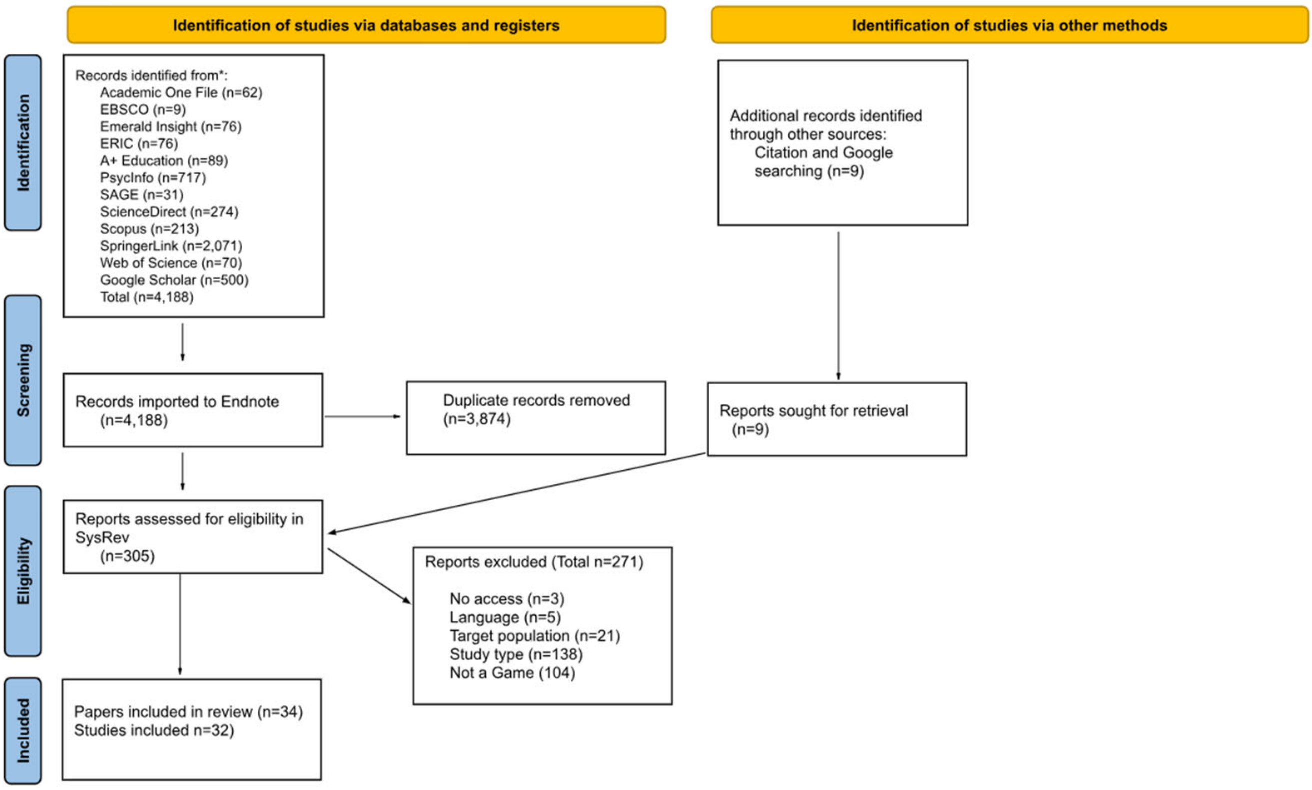

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA] flow diagram.

In total, 4188 references were identified. Of these, 3883 references were removed as 3540 of them did not match the inclusion criteria and 343 were duplicates. This process resulted in 305 items for closer inspection. After accessing the full texts of these items, another 271 items were removed. Reasons for that were no access (after two failed attempts to contact the corresponding authors) (n = 3), not in the English language (n = 5), not the right target population (n = 21), not the correct study type (n = 138), and not about non-digital games (n = 104). The final synthesis and analysis included thirty-four (n = 34) peer-reviewed publications, of which one (n = 1) was a peer-reviewed conference paper, and the rest were peer-reviewed journal articles (n = 33). Across the 34 publications, there were 32 distinct studies (Figure 1). Bragg produced three papers [21–23] from the one thesis study [24] that met the inclusion criteria for this systematic literature review (see Table S1 in Supplementary Materials).

3.6. Data Extraction and Analysis

Despite data extraction ideally being conducted by two independent reviewers, time and resource constraints necessitated data extraction to be largely conducted by one author. However, in adherence with strict Cochrane systematic review guidelines [17] to have at least two independent reviewers extract at least the data of reported outcomes, all four authors were involved in this process. In those cases where the results differed, a discussion followed until a consensus was achieved. The study characteristics were identified by conceptually mining the included studies for the following components: first author, publication year, country of study origin, population, setting (including control groups if any), data-collection method, study design (quantitative, qualitative, mixed methods, pre/post), game or intervention details, and reported outcomes. Study characteristics are presented in tabular form (Table S1 in Supplementary Materials). Data were thematically analyzed.

3.7. Quality Appraisal

The quality of the included studies was appraised with the mixed-methods appraisal tool (MMAT) [25]. The MMAT is a validated tool designed to be used for the appraisal of qualitative, quantitative, and mixed-methods studies included in a systematic review. The five categories of studies that can be appraised include qualitative research, randomized controlled trials, non-randomized studies, quantitative descriptive studies, and mixed-methods studies. It is required to answer five distinct questions pertaining to the methodology of the studies depending on the category, plus an additional five questions for mixed-methods studies. All four authors were involved in the quality appraisals, with each study being independently assessed by two reviewers. The results were compared and discussed until a consensus was achieved.

4. Results and Discussion

This systematic literature review provides up-to-date evidence on approaches that utilize non-digital games in mathematics learning. The results and discussion are presented together in this section and organized in the following paragraphs under the corresponding research questions.

4.1. RQ1. What Are the Characteristics of the Included Studies on Non-Digital Mathematical Games in Primary School Settings?

The study characteristics [17] included the year published, country of origin, study participants, game/intervention details, mathematical focus, study design, data-collection method, activity meeting the definition of a game, game mechanics, and reported outcomes (see Table S1 in Supplementary Materials).

4.1.1. Year of Publication

The largest number of articles were published in 2020 (n = 7). Four studies each were published in 2018 and 2012; three each in 2019, and 2004; two each in 2022 and 2021; and one each in 2017, 2016, 2014, 2011, 2010, 2009, 2007, 2005, and 2003. No articles were found from the years 2015, 2013, 2008, and 2006.

There have been more papers published relating to non-digital games in the last five years compared with any other five-year period since 2003. The notable increase in publications of these specific criteria selected studies over the last five years suggests that the aforementioned gap between the quantity of research into non-digital mathematical games compared with their broad usage in the classroom is narrowing.

4.1.2. Country of Origin

The largest proportion of the included studies were from three countries, including five each from Australia, Indonesia, and the USA; two each from Canada, Germany, and

Turkey; and one each from China, Iran, Malaysia, Nigeria, New Zealand, Poland, Romania, Saudi Arabia, South Africa, Switzerland, and Trinidad and Tobago (Figure 2).

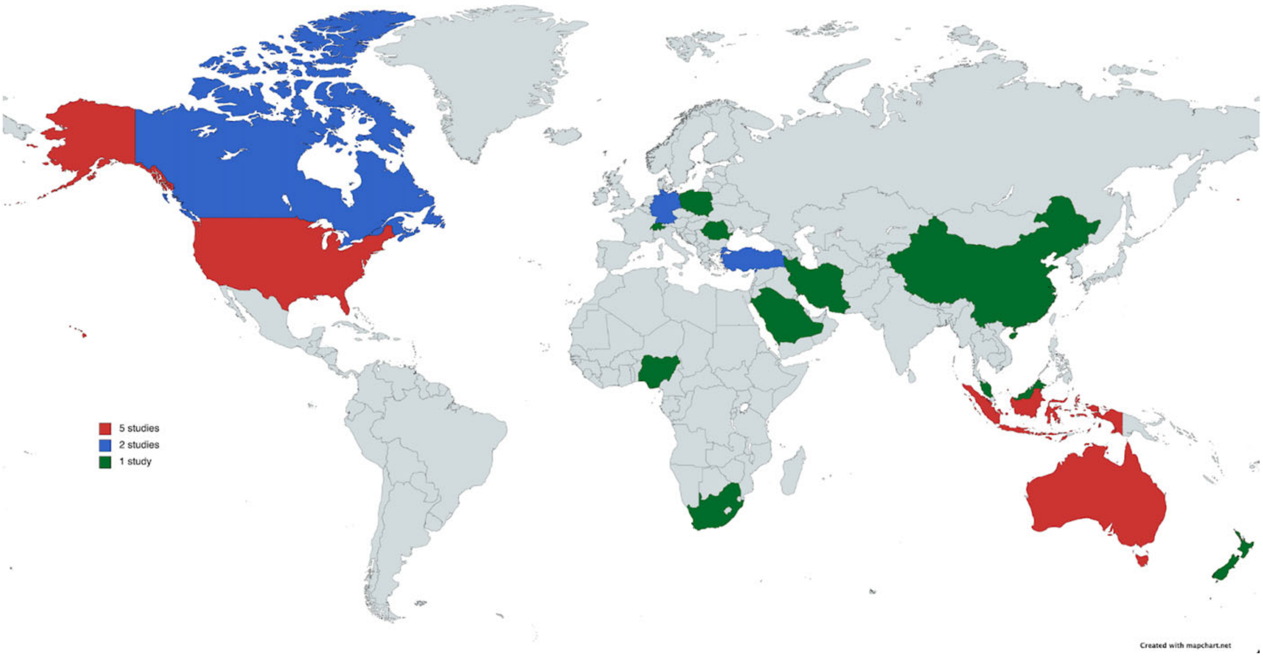

Figure 2. Distribution of included studies across countries of origin.

There is evidence that the concentration of research across countries is somewhat different for research into non-digital games compared with mathematics education research more generally. For example, whereas almost half of the high-quality English-language mathematics education research articles reported on research conducted in the United States (43%, [26]; 46%, [27]), this was only the case for around one-sixth (5 out of 32) of the studies in the scope of our systematic review. By contrast, Indonesia and Australia had the same number of studies in the scope of our systematic review as the United States, despite Indonesia not being listed in the top 10 countries in terms of the quantity of high-quality English-language mathematics education research articles published, and Australia generating only around one-twentieth of the research articles focused on mathematics education more generally [26,27]. Although there are likely multiple reasons for these differences, one factor may be that game-playing to support learning is more prevalent in particular countries, cultures, and communities than others. Indeed, using games to support mathematics instruction is a particularly prevalent pedagogical practice in Australian primary school schools [1], whilst Indonesian researchers have often emphasized the importance of traditional Indonesian games across the various Indonesian cultural groups and their potential for supporting curriculum-focused learning in school settings [28]. This has resulted in Indonesia exhibiting an emphasis on the integration of mathematics games within its educational system, reflecting a concerted effort to enhance pedagogical approaches and foster a deeper mathematical understanding among students. Evidence-based research has led Indonesia and UNESCO to collaborate and translate 29 mathematics games into 26 local languages in 2023 [29]. This strategic shift underscores Indonesia's commitment to promoting interactive and engaging mathematics instruction as a means to augment overall mathematical proficiency in its schools [30].

4.1.3. Study Populations

Twenty-five (n = 25) studies focused solely on students, six (n = 6) collected data from students and teachers, and one (n = 1) from teachers only [31]. Based on typical year level categorizations in Australian schools, students were enrolled in kindergarten through

Grade 2 (n = 11), Grades 3 to 4 (n = 7), Grades 5 to 6 (n = 7), and Grades 7 to 8 (n = 5), which is equivalent to middle school in some countries (see Figure 3). One (n = 1) study was conducted in 162 students' home settings [16] and one (n = 1) in an after-school program setting for primary students, yet specific age levels were not defined [32].

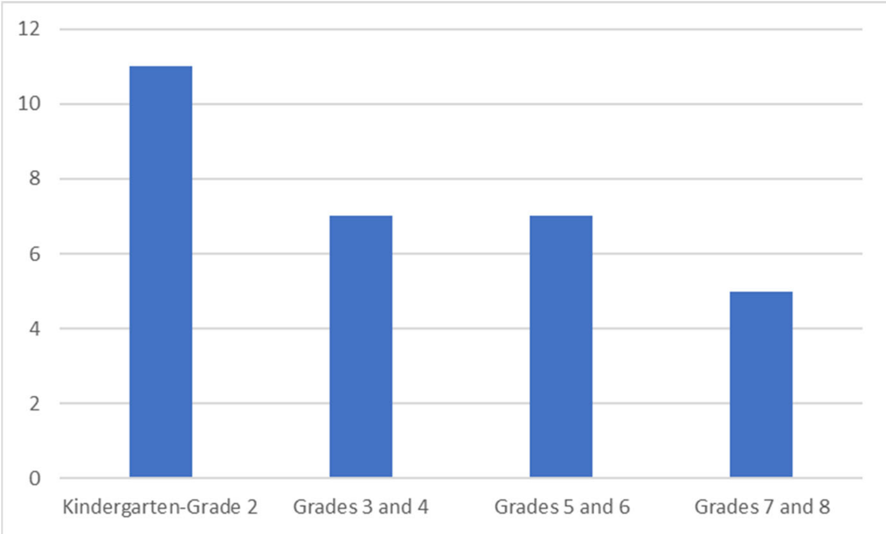

Figure 3. Distribution of grade levels of student participants.

A review of the included studies illustrates the diverse range of investigations focused mainly on the student experience. Although there are several studies that have included data from teachers, the lack of studies centered on the teachers' role in facilitating gameplay is consistent with Russo et al.'s [1] observation that how teachers use games has not been a focus of prior research when compared with the focus on the student experience. The focus on researching games in the early primary years is perhaps not surprising, given that games tend to be infrequently used in secondary school mathematics classrooms [33,34].

The numbers of student participants ranged from 4 to 222 and teacher participants from 1 to 35 (see Figures 4 and 5). This suggests that large scale quantitative studies involving non-digital games are comparatively rare, with most studies into games occurring within a single school context, generally involving students from a limited range of specific grade levels, and, on occasion, their teachers.

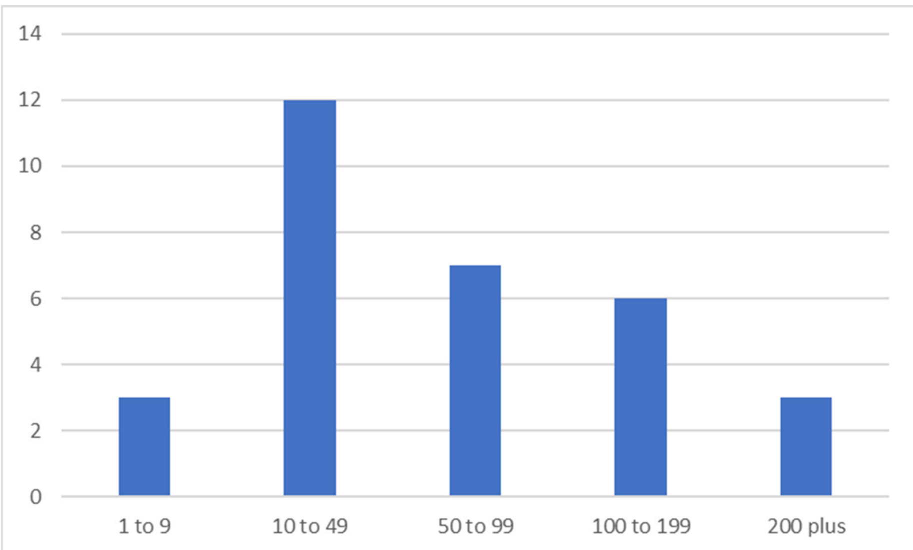

Figure 4. Quantity of student participants across all studies.

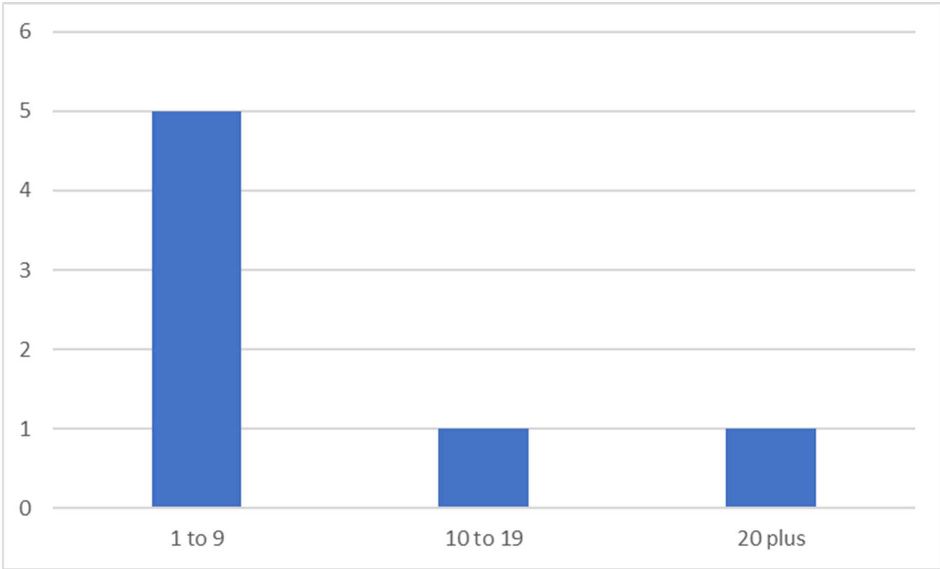

Figure 5. Quantity of teacher participants across all studies.

Eight studies reported the socioeconomic status of the participants. Overall, students were recruited from a range of backgrounds, with some studies targeting students who were socioeconomically disadvantaged or had additional needs. Students recruited in five of all the included studies were specified to be from a low socio-economic background [12,35–38] and in one study from low- to middle-income families [39]. One study each recruited struggling students [40], students with a lower-end achievement score [38], or students with a hearing impairment [41].

4.1.4. Game/Intervention Details

The types of games provided can be classified into board games [36,40,42–47], card games [16,32,36,41,47–50], calculator games [12], puzzles [45,51], drama-based games [52,53], outdoor activity games, including sport [35,54,55], game-based worksheets [56], the traditional Indonesian game Jirak [57], fractions manipulatives game [31], and tangram and origami [58]. The remaining studies incorporated multiple types of games into a single study and included but were not limited to self-made games from paper bags, dice games, bingo, battleship, finger twister, deal or no deal, and pattern blocks [15,32,37,39,59–61].

The most commonly employed approach for playing the games was group-based, with students playing in small groups of 2–6 players or two teams competing (n = 11). Other approaches included a whole classroom setting (n = 10), playing in pairs (n = 8), individual gameplay (n = 2), gameplay in pairs where the student was assessed by the teacher (n = 2), and in one study (n = 1), a parent playing with their child.

Intervention length varied greatly, from 2 to 4 days up to 8 or 12 weeks and 6 months or 1 year. Consequently, there was great variability in the number of sessions provided within these intervention timeframes. Reported information on the total exposure time per intervention ranged from 5 min in a physical education setting [55] and games situated in the home [16] to over 16 h in drama classroom activities [52] and in nature and historical places [35].

4.1.5. Definition of a Game

Around one-third of the studies (11 out of 32; 34%) incorporated mathematical games that were verifiably fully consistent with the definition of a mathematical game as outlined earlier in the review. The remaining 21 studies used games that did not meet one or more criteria, or used games that were described in insufficient detail (e.g., [52]). In particular, several studies outlined game-like activities that were mathematical, competitive, and had a clear objective; however, they did not involve any strategy or choice for players. For example, Casey et al. [16] described an activity that involved two players each receiving three playing cards, with the player whose cards summed to the highest total being the winner of the hand. Similarly, Skillen et al. [44] described a modified version of snakes and ladders, which included an enhanced gameboard and modified mechanics to focus student attention on the counting-on strategy. Despite these modifications, the Skillen et al. [44] game is similar to the original snakes and ladders in that it does not involve any player choice or strategy but is merely a 'luck race' [11].

4.1.6. Competitive Games versus Collaborative Games

From the 32 studies, 21 incorporated games that could be classified as competitive (n = 15), collaborative (n = 4), or that involved multiple games encompassing some that were competitive and some that were collaborative (n = 2). The remaining 11 studies either described game implementation in insufficient detail for the structure to be gleaned or were 'solo' games, where students were not competing against others nor were they collaborating. It is noteworthy that studies that involved students collaborating were reasonably unusual. Examples of studies involving collaboration included McFeetors and Palfy [15], where pairs of students competed in strategy-type games against other pairs of students, and Cichy et al. [54], where the class was divided into two teams that competed against each other but collaborated amongst team members. Played either competitively or collaboratively, non-digital games within the mathematics classroom are predominately a social activity between two or more players.

4.1.7. Mathematical Focus

Similarly to Ersen and Ergül's [62] examination of trends in game-based mathematical learning, the mathematical content areas addressed in the papers were categorized broadly according to the National Council of Teachers of Mathematics (NCTM) standards [63] with five content areas: number and operations, algebra, geometry, measurement, data analysis, and probability.

Overall, 30 studies utilized games that could be classified to mathematics content areas [63], with two studies providing insufficient detail to be given a mathematical content classification [43,57]. In addition, four studies were classified to two content areas, including geometry and measurement [58], geometry and multiplication [56], geometry and strategy, logic and reasoning [32], and addition and subtraction and multiplication and division [48]. The majority of studies (18) had links to various areas of number and operations. The next most common content area being geometry (6), probability was the focus in two papers [39,60], and Kaloo et al. [58] was the only paper to explore measurement in games.

An examination of the mathematical focus [63] revealed that, at least in the studies in the scope of this review, there was a preference for incorporating number-focused games into classroom activities. This is perhaps not surprising, given that counting and number recognition are two basic number skills that are often utilized in games [64,65]. This strong emphasis on number games may stem from educators' deliberate efforts to engage students in practicing number concepts in an enjoyable and interactive context, thereby facilitating a deeper understanding of these foundational mathematical concepts. Indeed, there is evidence that teachers strategically employ mathematical games as a pedagogical tool to mitigate the sense of anxiety that students may associate with mathematics [66], supporting a more engaging and positive learning environment [67].

Additionally, the choice of selecting number games may be influenced by their potential for the ease of measuring outcomes in achievement tests, thus simplifying teachers' capacity to assess students' progress in mastering number concepts. This alignment with measurable learning outcomes could further underscore the appeal of number games for inclusion in research studies, offering a quantifiable means to gauge the effectiveness of these pedagogical tools in improving students' mathematical understanding.

A related point that needs to be acknowledged is that the inclusion criteria employed in this systematic review may have inadvertently introduced bias in favor of papers concentrating on number games and their learning outcomes. By specifying criteria that emphasized research papers with stated student outcomes, such as academic achievement and performance, it is possible that papers exploring other aspects of games usage (e.g., how teachers perceive probability concepts to be embedded in games) may have been underrepresented in the final selection. This potential bias should be considered when interpreting the findings, recognizing that a broader range of research into games exists beyond the confines of the measurable outcomes [63] associated with number games.

Interestingly, the analysis revealed that there was a noticeable absence of games employed that focused on exploring measurement. Only one paper described the experience of playing a measurement-focused game [58]. Furthermore, it is worth noting that no games centered on statistics were identified in our review. Further probing is necessary to determine whether this absence is indicative of a deliberate pedagogical choice or if it reflects a lack of suitable educational games addressing these specific areas of mathematics. Are there limited educational games available that effectively explore measurement and statistical concepts at the primary school level? Could this omission be indicative of a gap in the educational gaming landscape that warrants future exploration and the development of measurement-based and statistics-based games for primary education? Alternatively, we should consider whether games may not be a suitable vehicle for comprehensively exploring measurement and statistical concepts, thereby raising questions about the feasibility of integrating measurement and statistics education into game-based learning approaches. These questions merit further investigation to inform the development of effective, engaging, and well-rounded selection of mathematical games in the primary classroom.

4.2. RQ2. How Does Playing Non-Digital Games Impact Student and/or Teacher Outcomes in Primary School Settings?

Across the studies, playing games in the mathematics classroom revealed effects on: students' academic performance and learning outcomes; mathematics anxiety; students' communication and critical thinking skills; students' motivation; and students' attitude. Each of these aspects is discussed in turn.

4.2.1. Academic Performance and Learning Outcomes

Seventeen studies investigated the effectiveness of game-based teaching approaches in improving students' academic performance and learning outcomes. Bahrami et al. [59] found that the game-based teaching group achieved higher scores in learning and retention tests compared to traditional teaching, except for the concept of correspondence. Bragg [22] observed minor gains in all experimental treatment groups, with the largest improvement seen in the games without discussion group. Teacher-led discussions during and following gameplaying did not enhance children's learning. Moreover, groups exposed to rich tasks outperformed the games-based groups at follow-up. Adewale and Taiwo [45] found a significantly higher performance in both experimental groups compared to the control group. The study identified group discussion (GD) as the most facilitative approach, followed by problem-based learning with worksheets (PW). Moreover, no significant gender-specific effects were observed on student achievement. Celik [35] conducted a study that revealed a significant difference in the pre-test and post-test geometry scores of the outdoor 'modeling' group, collaborative learning group, and control group, whereas there were no differences in students who participated in the in-class mathematical games group. However, controlling for pretest scores, the students in all three experimental groups outperformed the students in the control group. Cichy et al. [54] investigated the impact of participating in physical classes using Eduball and found that it resulted in a faster acquisition of mathematical skills and knowledge. The experimental group showed a significant improvement in all tested mathematical categories compared to the control group. Additionally, Kamii et al. [36] found that the students in the experimental group compared to the control group demonstrated a superior performance in mental arithmetic and logical reasoning. Karnes et al. [40] conducted a study using a mathematics racetrack game and observed a substantial improvement in performance (accuracy and speed) in all students, with scores being maintained after a three-week follow-up. Markey et al. [41] explored the impact of an intervention on students' understanding and application of fractions and mathematical language. The findings indicated that the students showed a good understanding and application of fractions. Skillen et al. [44] investigated the effects of different strategies on early number skills. The study demonstrated significant and stable improvements in early number strategies, particularly in the count-on condition. Moreover, Singh et al. [50] found students' ability to think quickly, perform mental computations, and solve problems improved through a game-based learning approach. Casey et al. [16] found that maternal support in providing mathematics fact hints was positively associated with the child's later addition accuracy. Similarly, Debrenti and Laszlo [48] observed significant improvements in the experimental group's mental computation skills and efficiency in problem solving. Kaloo et al. [58] demonstrated a significant improvement in students' academic performance, specifically in geometry content knowledge, through game-based teaching. Liang et al. [37] found that an intervention targeting number sense resulted in significant improvement, which persisted for two months. Vogt et al. [47] reported significantly higher learning outcomes in quantity-number competencies for students engaged in play-based mathematics compared to traditional kindergarten. Vetter et al. [55] reported a significantly greater improvement in learning multiplication tables in the playground compared to the classroom condition. Young-Loveridge [38] found that participation in an intervention program, which included mathematical games, led to increased numeracy levels and significantly greater gains in numeracy that remained statistically significant for over a year after the program finished.

4.2.2. Mathematics Anxiety

Two studies reported the impact of non-digital games on mathematics anxiety. Alanazi [52] found that the experimental group exhibited significantly lower mathematics anxiety scores and higher performance scores compared to the control group. Gürbüz [39] reported that game-based teaching, combined with cooperative learning groups, led to improvements in students' motivation, understanding, attendance, and helped them to overcome mathematics anxiety.

4.2.3. Communication and Critical Thinking Skills

Six studies described communication and critical thinking skills during non-digital game play. Andayani [51] reported that both groups showed an improvement in mathematical communication skills, but the gains were significantly higher in the Gedrik Saruk Indeed Seru (GESAMSU) group compared to the control group. McFeetors and Palfry [15] highlighted the capability of students to reason through multiple experiences of developing convincing arguments in an authentic context. Indriani et al. [43] found that engaging in problem-based learning supported by a monopoly game improved students' critical thinking skills. Bragg [22] investigated the impact of game-playing lessons on student engagement and communication. The findings revealed that students in game-playing lessons exhibited a greater incidence of talk related to the mathematical task compared to non-game-playing lessons. Similarly, Putra et al. [53] found that game engagement fostered active communication among students and facilitated the development of mathematical ideas. Heshmati et al. [31], however, found that teacher–student interactions were of lower quality during games compared to non-game lesson segments.

4.2.4. Emotion and Motivation

Three studies reported on emotion and motivation and non-digital games. Nisbet and Williams [60] found improvements in students' enjoyment, motivation, and perceptions of the usefulness of chance in their lives. Similarly, teachers reported high levels of student enthusiasm and motivation. Nizaruddin et al. [57] investigated the impact of a game called 'Jirak' on student achievement and mathematical disposition. The findings demonstrated higher levels of average student achievement and mathematical disposition in the 'Jirak' game group compared to the traditional learning group. Additionally, Rajotte et al. [46] explored the influence of daily routines involving games and logical challenges on student motivation. The study found that such routines improved motivation and acted as an external component of school motivation.

4.2.5. Attitudes

Two studies described changes in student attitudes after playing non-digital games. Bragg [21] found that a portion of students did not indicate a shift in attitudes towards mathematics as a consequence of playing games. Moreover, her study revealed that while some students felt that games helped them to learn mathematics, a considerable number of students indicated that mathematics games did not aid their learning. It appeared that some students did not value games as a learning tool, and it was speculated that the placement of attitude scales on the front page of the achievement test may have resulted in more negative attitudes towards games than would otherwise have been the case. Conversely, White and McCoy [61] reported significant improvements in students' attitudes towards mathematics as a consequence of playing games.

4.2.6. Other Outcomes

Herbert and Pierce [42] found that students developed higher-order thinking skills, spatial visualization, and logical reasoning while playing games. Marshall [32] observed that students constructed interpretations and applied logical reasoning as they played puzzle games. Van Putten et al. [56] reported improved academic achievements, confidence, skills, and understanding in mathematics through game-based approaches, particularly in the topics of multiplication and division. In addition to significant improvements in students' attitudes towards mathematics, White and McCoy [61] reported enhanced achievement in ordered pairs, growth mindset, problem-solving skills, and student engagement as a result of engaging in game-based learning.

4.2.7. Teacher Outcomes

We acknowledge that teachers are instrumental in the delivery of non-digital games to support mathematics learning. Although a number of studies included in this systematic review reported on student outcomes as perceived by teachers, teacher outcomes were not presented. This confirms previous findings in the literature regarding limited reporting of teacher outcomes when using non-digital games in the mathematics classroom [1].

4.2.8. Summary

The studies included in the review are particularly notable for the broad range of outcomes they considered. Most studies indicated that game-based mathematics learning had a positive impact, although, on occasion, the comparative impact of playing games was ambiguous [21,22,35] or somewhat negative [31]. Indeed, overall, the research indicates that playing mathematical games has generally resulted in improved mathematical learning and dispositional outcomes for students either over time or when contrasted with groups of students engaged in other mathematical activities. Games seem capable of improving mathematical proficiencies, including conceptual understanding [41], procedural fluency [40], mathematical reasoning [32], and problem solving [61]. This is consistent with the pedagogical aims teachers report when teaching mathematics through games reported elsewhere [1]. Moreover, playing games has been associated with reduced mathematics anxiety [52], increased motivation to learn mathematics [46], enhanced critical thinking [43] and communication [51] skills, and more positive attitudes towards learning mathematics [61]. There was some evidence that outdoor games and activities had a more positive impact on student learning outcomes compared with classroom-based activities [35,54,55].

4.3. RQ3. What Is the Methodological Quality of the Included Studies?

Across the 34 included papers, a total of 17 employed quantitative designs, while 7 publications used qualitative designs. Additionally, 10 studies adopted mixed-methods designs, which involved combining quantitative and qualitative data collection and analysis techniques. The majority (n = 22) of the total number of publications were pre/post designs, and most of these 22 studies incorporated a control group (n = 18).

Employing a rigorous ranking system for evaluating research papers based on their methodological value is critical for fostering scholarly progress and building confidence in the quality appraisal process. Hong et al. [25]'s five-star ranking system offers a clear framework that aligns with established academic practices, facilitating the effective identification and differentiation of paper quality. Table 1 details the quality appraisal of the included studies.

Table 1. MMAT: study quality appraisal (study denoted by the first author).

Stars	Ranking	Qualitative	Quantitative	Mixed	Total
5 100%	High	McFeetors [15]	Bragg (2012a) [22] Cichy [54] Kamii [36] Liang [37] Vetter [55]	Heshmati [31] Vogt [47]	8
4 80%	High	Gürbüz [39] Marshall [32]	Adewale [45] Alanazi [52] Bragg (2012b) [23] Casey [16] Karnes [40] Skillen [44] Young-Loveridge [38]	Bragg (2007) [21]	10
3 60%	Medium	Prahmana [49] Putra [53]	Bahrami [59] Debrenti [48]	Kaloo [58] White [61]	6
2 40%	Medium	Herbert [42]	Nizaruddin [57] Rajotte [46]	Singh [50] Van Putten [56]	5
1 20%	Low		Andayani [51]	Celik [35]	2
0 0%	Low	Markey [41]		Indriani [43] Nisbet [60]	3

We have proposed a sub-level of ranking these papers, assigning five and four stars [25] to high-quality papers. This reflects these papers' more robust methodologies, which are indicative of the validity and reliability of findings. Designating three and two stars [25] to medium-quality papers acknowledges these papers' potential contributions while signaling the need for further methodological refinement or increased disclosure of the methodology as required. Assigning one and zero stars [25] to low-quality papers underscores the significance of methodological integrity in maintaining scholarly rigor and credibility. The incorporation and analysis of outcomes from papers with high, medium, and low methodological value is purposeful, as this approach enables a comprehensive understanding of the scope of research methodologies employed to examine non-digital mathematical games. Using this approach, over half (n = 18) of the papers in this systematic review are classified as high quality, 11 papers are classified as medium quality, and only 5 papers fall within the low range of methodological quality.

Data-Collection Methods

The data-collection methods encompassed a diverse range of techniques. As shown in Table S1 in the Supplementary Materials, the most utilized methods were achievement tests (n = 25), which served as tools for evaluating students' mathematical knowledge, problem-solving skills, and critical thinking abilities. Questionnaires or surveys (n = 9) offered an efficient means of gathering information on attitudes and experiences, whilst interviews (n = 14) allowed for more in-depth exploration of participants' perspectives. Other methods included video or audio recordings and photos (n = 8) to capture real-time educational activities, observations and field notes (n = 13), journal entries (n = 2), individual or group discussions, including teacher feedback (n = 3), examinations of student-produced artifacts and self-reflection (n = 2), and academic records (n = 2).

Achievement tests are traditionally a commonly employed tool in classrooms to assess students' mathematical knowledge and skills, and therefore, it is not surprising that the most frequently used method to collect data related to mathematical capabilities was achievement tests. Interestingly, despite games being viewed as a non-traditional approach to teaching, there were few studies that employed an examination of the students' gameplay to assess their mathematical understanding. McFeetors and Palfry's [15] study is an example of an examination of gameplay to unpack student learning. The authors analyzed photos of gameplay to determine growth in learning, as well as students' record sheets, observational records of students' interactions, and interviews, which combined to assist the researchers in gaining a holistic picture of students' gains in strategic thinking and reasoning through gameplaying.

5. Conclusions

This review has shed light on the state of research into non-digital games over the past two decades. With regards to our first research question examining the characteristics of the included studies, several key points are worth noting. First, there has been a notable increase in publications incorporating non-digital games over the past five years, perhaps reflecting a narrowing of the gap between the prolific use of games in primary classrooms and the relative lack of research focus in this area. Second, games research is relatively geographically diffuse, although some countries are over-represented in terms of their contribution to non-digital games-based research compared with their contribution to mathematics education research more generally, with Indonesia and Australia being the two most notable examples. Third, although the majority of research into mathematical games has adopted quantitative methods, and focused on students only (as compared to students and teachers, or exclusively teachers), most studies have generally been comparatively small-scale and often involved specific grade levels within individual schools. Fourth, many studies have used the term mathematical game comparatively loosely and have not described in detail how the activity used in their study meets the relevant criteria to be classified as a mathematical game. Finally, although an eclectic range of game materials, game types, and game structures are reflected in our review, in terms of the mathematical content focus of games, when a specific focus could be discerned, number games tended to dominate.

With regards to our second and third research questions, playing games was generally associated with a broad range of positive outcomes, encompassing both cognitive (e.g., improved mathematical performance, enhanced mathematical reasoning) and affective (e.g., reduced anxiety, higher levels of motivation) factors. These findings were generally gleaned from one or more of the following sources of data: improved performance on achievement tests; interviews with teachers and students; observations and field notes; and through students, and on occasion teachers, completing questionnaires or surveys. Interestingly, most studies were determined to be high quality using our quality appraisal tool [25]; however, this was driven by the fact that half of the studies adopted quantitative methodologies and that over two-thirds of these studies were deemed of high quality. By contrast, the majority of qualitative and mixed-method studies in the scope of the review were determined to be of low or medium quality.

5.1. Limitations

There are several limitations of our review that need to be acknowledged, which often reflected the eclectic nature of the field. Although our review spanned the period 2003 and 2022, only 32 studies met the inclusion criteria, suggesting that there were limited outcome-focused publications available on non-digital games for mathematics learning over this period. Moreover, the heterogeneity of the studies made it complex to determine the specific characteristics of the games or games interventions that resulted in optimum student and teacher outcomes. Related to this was the lack of clarity around how the authors defined games and how games were used to support a particular intervention. Studies that involved games that led to positive outcomes were often not discussed in detail and were quite disparate. Finally, a further limitation that should be noted at the review level is that publications were restricted to papers written in English, which limits the geographic representativeness of our systematic review. Notwithstanding these limitations, the review effectively synthesized evidence from quantitative, qualitative, and mixed studies and assessed the strength of these studies using the MMAT tool to shed light on our three research questions.

5.2. Future Research Recommendations

Future research should address the identified research gaps in the included articles in this systematic review. These articles revealed the scarcity of scholarly investigations concerning educators' decisions regarding the selection of educational games and the corresponding pedagogical actions undertaken by teachers within the classroom. The voices of teachers are underrepresented in the literature. Understanding the factors influencing teachers' perspectives, choices, and their pedagogical strategies employed with educational games can contribute to enhancing the effectiveness of game-based approaches to the learning of mathematics in diverse educational settings.

Additionally, the mathematical educational community would benefit from research that moves beyond the current emphasis on number games and explores the specific domains of measurement, probability, and data within games. Delving into these topics can foster a more comprehensive understanding of how games can be utilized effectively to teach and reinforce concepts related to these mathematical content areas. Furthermore, the integration of higher-order thinking games should be a focal point for future investigations, as these games can stimulate critical thinking, problem-solving, reasoning, and logical and analytical skills. This expansion into higher-order thinking games can diversify the educational benefits derived from games and cater to a wider range of learning objectives. By addressing these future research recommendations, educational researchers can further the field and inform teachers and policymakers on the best pedagogical practices for integrating games into educational settings to enhance students' learning of mathematics.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/educsci14020200/s1, Table S1: Characteristics of manuscripts included in the review (n = 34).

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