

Supplementary Materials.

Table S1. Characteristics of manuscripts included in the review (n = 34).

1st author Year Country	Population Ages Study setting	Game / intervention details	Data collection method	Study design	Reported outcomes
Adewale [45] 2010 Nigeria	n=222 students 5th grade students from two Primary schools in Akure South	Problem-Based Learning with Worksheets (PW): Tangram Puzzles – a Chinese game with a set of seven pieces of geometrical figures. Group Discussion: Sets of Geo-board to be used as instructional material under the guidance of the teacher to discover some basic geometrical concepts. Duration: 5 weeks, plus 1 week for post-test administration.	Mathematics Achievement Test	Quantitative Cohort study (3 groups) Pre/post Experimental PW n=67 Experimental GD n=77 Control n=78 (conventional teaching method)	Significantly higher performance in both experimental groups, compared to the control group. Group Discussion: was most facilitative followed by PW: No significant gender specific effects were found on student's achievement.
Alanazi [52] 2020 Saudi Arabia	n=58 students 1st year students at a primary school in Saudi Arabia	Active recreational mathematics games examples: movement story being read to the students about birds in a nest with some of them flying away, containing addition and subtraction questions. Students were asked to perform the movement story, the group that completes the task first and reveals the correct answer wins. Other examples include animals such as cats and dogs where students needed to imitate their sounds to get the results. Duration: 24 sessions over 2 months = 3 sessions per week/45 min each.	Mathematics Performance Test Questionnaire Anxiety Scale for Children	Quantitative Cohort study (2 groups) Pre/post Experimental n=28 Control n=30 (conventional teaching method)	Experimental group obtained statistically significant lower mathematics anxiety scores and higher performance scores than the control group.
Andayani [51] 2022 Indonesia	n=62 students 3rd grade students at the Islamic Elementary School (IT) Nurul Islam, Paramarta	GESAMSU (Gedrik Saruk Indeed Seru): environmental- based learning model, a floor puzzle game with dice and question cards and star rewards for a correct answer. Students move along the board through skipping across fields.	Essay test	Quantitative Cohort study (2 groups) Pre/post Experimental n=32 Control n=30 (conventional teaching method)	Students' mathematical communication skills improved in both groups; however, communication skills gains were significantly higher in the GESAMSU group compared with the control group (85.96/60.63)
Bahrami [59] 2012 Iran	n=62 students 1st grade female students at a randomly selected school in Khorramabad City	Games: numbers game, grabbing the handkerchief, one-way street, songs, etc. Example-one-way Street game was used to teach directions. Teaching materials: Mathematics course book, hula hoop, a rope, a light large ball, a light small ball, a basket, and number cards. Duration: 6 sessions, 45 min each.	Learning test Retention test	Quantitative Cohort study (2 groups) Pre/post (1 and 3 weeks after teaching each concept) Experimental n=31 Control n=31 (conventional teaching method)	In comparison to traditional teaching, the game-based teaching group had higher scores in learning tests (except for the concept of correspondence) and retention tests (concepts of left and right, correspondence, equality, less than and greater than signs, and addition and subtraction). There was no significant difference between the two groups in learning the concept of one-to-one correspondence, but a significant difference

					was observed in the retention of this concept.
Bragg [22] . 2012a Australia		Games – ‘Guestimate’ and ‘Hone on the Range’. Guestimate - The aim of the game is to be the first player to reach the nominated target of 100 (more precisely, any number between 100.000 and 100.999), so answers such as 100, 100.678 and 100.9 are considered winning results. Hone on the Range follows the same procedure as Guestimate, but the players aim for a target in the range between two given numbers, e.g., 750 and 780. Duration: 2 sessions/week/4weeks. Game without discussion group – 35 min of independent game playing. Game with discussion group – 15 min of teacher-led whole class discussion, both during and after the game. Activities group – 35 min of rich and varied non-game learning activities aimed at teaching the same content.	Written achievement tests	Quantitative Cohort study (3 groups) Pre/post, and 10-week delayed post-test Game without discussion group n=32 Game with discussion group n=44 Activities group n=36	Minor gains for all experimental treatment groups in the study, with the largest gain in the games without discussion group. Students across the groups not only sustained their prior test results but also showed some improvement, except for the Games with discussion group. The activities group made the most gains overall. In conclusion, there were lesser gains in learning in game playing situations versus non-game activities and that teacher-led discussions during and following the game playing did not improve children’s learning.
Bragg [23] 2012b Australia	n=6 students Ages: 9-12 years Composite class grades 5/6 students from a primary school in a lower socioeconomic area of suburban Melbourne.	Games – ‘Guestimate’ and ‘Hone on the Range’ (see above) Duration: 10 mathematics lessons (8x game playing, 2x non-game playing). 1 session = 35 min = a total of 7 h classroom lessons, over 4 weeks. Non-game-playing lessons included reading and interpreting various graphs created by the teacher. The students were provided with several labelled graphs and answered a series of questions about them. Then, students created graphs to exchange with their partner to answer the same questions. The second lesson involved articulating and sharing mental computation strategies employed to obtain selected targeted numbers using the four operations.	Observations: Task-oriented anecdotal	Quantitative Cohort study (1 group)	93 % of students in the game-playing lessons exhibited on-task engagement compared with 72 % during the non-game-playing lessons. Greater incidents of student talk related to the mathematical task in game-playing lessons (34 %) compared with the non-game playing lessons (11 %).
Bragg [21] 2007 Australia	n=121 students 5th and 6th grade students from 8 classes in 3 primary schools in Melbourne	Math games. Duration: total of 8 sessions: 2 sessions/ week/4 weeks	Attitude scales Semi-structured interviews	Mixed methods Cohort study (4 groups) Pre/post/delayed Game with discussion group n=44 20 minute game group n=48 35 minute game group n=32	37% of the students in the game-playing groups did not indicate a shift in attitude between the pre-instructional period and immediately after. 14% of students felt that games helped them learn mathematics, however, 49% indicated that the mathematics games did not help them to learn. In contrast, interview data

				Activities group n=36	showed that students felt comfortable with game-playing and that it had assisted them in developing an awareness of other skills such as problem-solving.
Casey [16] 2020 USA	n=162 students Ages: 6-7 years 1st grade female students recruited from 39 regular education classrooms in two North-eastern public-school districts The study was conducted in the student' home settings	Card-game: Each player received three number cards from a traditional deck of cards (the face cards were removed). The players needed to identify the player with the highest sum, based on the numbers on their three cards. Without given game instructions, mothers used varying strategies to provide support as the girls added up the total on the cards or estimated who had the highest total. Duration: 1 home visit: conducted between October and April; 5 min play between mother and child.	Mathematics performance tests Video recordings (home visits)	Quantitative Case study	Maternal support in terms of providing math fact hints was significantly and positively associated with the child's later addition accuracy. Neither of mothers' suggestions for using a count-on strategy or to try an estimation strategy were significantly associated with later math skills or performance in their daughters, including the subset of girls who scored at or below the median rate value in terms of how many problems the child solved on their own.
Celik [35] 2020 Turkey	n=101 students 3rd grade students from 3 different public primary schools with low socio-economic levels in a province of the south-eastern region of Anatolia	Activities of all groups were held in nature, historical places, or at school. Group A modelling: Example - trekking and planting trees, to explore geometric shapes found in nature. Group B collaborative: Example - divided into 3 teams, students were asked to observe logs, garbage bins, bridge legs, etc. in their environment that looked like prisms and cylinders, and discuss these. Group C Game-based: Example – The properties of geometric shapes were examined by the students with the cube rolling game. Planting saplings. The students could find the objects that exemplify lines, half-lines, and line-segments with the string model. Control group: The existing instruction was followed. Duration: per group 24 class hours over 6 days	Geometry success test Structured interviews	Mixed methods Quantitative part: Cohort study (4 groups) Pre/post Experimental n=65 (randomly assigned to either the modelling (n=21), collaborative (n=22) or game-based learning groups (n=22) Control n=36 (existing instruction method)	Significant difference between the pre-test and post-test scores of the modelling, collaborative learning, and control groups, but no significant difference in the game-based learning group. Students' success in geometry was greatest in the modelling group, followed by the collaborative learning group. There was no significant difference from pre to post test in the game-based learning group. Geometry activities in nature were more effective than in-class activities.
Cichy [54] 2020 Poland	N=47 students Ages: 7 years 1st grade students	Eduball: a set of 100 balls used for mini-games for teams in five colours (yellow, green, blue, red, and orange) with painted (in black) letters of alphabet (large and small letters), digits from 1 to 9 and 0, mathematical operation symbols [addition (+),	Mathematics test	Quantitative Cohort study (2 groups) Pre/post Experimental n=25 Control n=22	Participating in physical classes using Eduball caused a faster acquisition of mathematical skills, knowledge, and mathematical imagination. Children from the experimental

		subtraction (-), multiplication (\times), division (\div), greater than ($>$), smaller than ($<$), and brackets () and symbols of the electronic mail (@) Duration: Experimental class - two/three 45-min physical exercise classes a week were carried out using Eduball. Control class - all three 45-min physical exercise classes were taught without using educational balls. Intervention provided over 1 year.			group improved their results significantly in all mathematical categories tested (sets and their elements, natural numbers and positional notation, addition and subtraction, multiplication, and division, counting money, geometric shapes and measuring length, measuring volume and mass, and measuring time). Students from the control group improved their results only in four of these categories (natural numbers and positional notation, addition, and subtraction, counting money, and measuring time), and these changes were lower than in the experimental group.
Debrenti [48] 2020 Romania	n=30 students Ages: 8-9 years 2nd grade students at an elementary school in in Oradea	5 different card games, each student had to try each game at least once. 2 games were detailed in the study: Rock-paper-scissors and Halli Galli. Duration: 10 lessons over 2 months.	Mental computation test	Quantitative Cohort study (2 groups) Pre/post Experimental n=15 Control n=15 (conventional methods)	Significant improvements in the experimental group in mental computation skills and time spent on solving the problem. No significant changes between pre- and post-test in the control group.
Gürbüz [39] 2014 Turkey	n=24 students n=1 teacher 4th grade elementary students from low to middle-income families	3 Games: "Which Spinner?", "Drawing Ball", and "Deal or No Deal?" 7 groups of 3-4 students. Duration: a total of 3 class hours.	Semi-structured interviews Journal entries Audio and video recordings Teacher feedback	Qualitative	The game-based teaching environment with the cooperative learning groups led to improvements in students' motivation, enabled students to work with peers, facilitated understanding, enhanced attendance, helped students to overcome math anxiety and to combine learning and fun.
Herbert [42] 2004 Australia	n=9 students Ages: 12-13 8th grade students at an Australian secondary school located in a provincial city	5 board games were played: Mancala, Bagha-Chal, Nine Men's Morris, Go Moku, Backgammon. First stage: students playing a variety of traditional strategy games. Each week the students played the same game for the entire session and swapped partners and games throughout the 12 weeks. Second stage: students designed, constructed, and trialled their own strategy games. Duration: 12 weeks/50 min sessions during class time.	Observation notes (researcher) Individual and whole group discussions Weekly game evaluations and student reflections Student-developed games	Qualitative	Students developed their higher order thinking skills of analysis and synthesis as they played games and planned strategies of increasing complexity. Students also showed an improvement in the higher order skills of spatial visualisation and logical reasoning as they visualised the possible outcomes of their opponent's moves and constructed a countering

			examination and photos		plan for several moves in advance.
Heshmati [31] 2018 USA	n=14 teachers 5th grade classroom in elementary school	Games: 'Cover-up' and 'Un- cover'. Both games were designed to help students develop a concrete understanding of fractions. Duration: 14 teachers/5 lessons each=70 lessons in total. Of those 70 lessons, 14 lessons utilised games (1 lesson per teacher), the rest were lessons without games. Each game segment = 15-20 min.	Video recordings	Mixed methods Quantitative part: Observational	Teacher-student interactions were of statistically significantly lower quality during games than during non- game segments with similar instructional purpose.
Indriani 2019 Indonesia	n=72 students Ages: 12-13 years 2nd grade students at SMP N 18 (Middle School) Semarang	Customised mathematical Monopoly game to assist with PBL. Duration: 4 sessions	Academic records Critical thinking skills test Documentation Interviews Questionnaire	Mixed methods Quantitative part: Other Cohort study (2 groups) Experimental n=36 Control n=36 (PBL only)	Engaging in problem- based learning supported by a monopoly game improved students' critical thinking skill, compared with engaging in problem-based learning alone.
Kaloo [58] 2019 West Indies	n=22 students Ages: 10-11 years 6th grade primary students at a private, co-ed school in Trinidad and Tobago	Game: Tangrams and Origami. Students played either game in teams of 2 or 4 players. Duration: 4 x 60 min sessions (2 x Origami, 2 x Tangram).	Mathematical test Questionnaire Observations (teachers) Open-ended interview (teachers)	Mixed methods Quantitative part: Cohort study (1 group) Pre/post	Students: Statistically significant improvement in students' academic performance (geometry content knowledge). Although there was variability in whether games were optimally challenging (too hard, too easy, just right), students enjoyed playing the games, and were motivated by opportunities to collaborate and be creative. Students would have preferred clearer instruction for gameplay, and to work with less complex shapes. Teachers: The games reinforced concepts and relationships in geometry, and increased student engagement and team collaboration.
Kamii [36] 2005 USA	n=46 students 1st grade low- performing elementary students from 2 different schools in the same low-SES neighbourhood, California	Games/activities: Stage 1 – physical knowledge games - 'Pick up sticks', 'Bowling', 'Balancing Cubes', 'Piggy Bank'. Daily engagement in a variety of physical knowledge games during the first half of the year. After the winter break, easy addition games were introduced to test student's readiness to learn arithmetic. Stage 2 – arithmetic games and word problems. Those who did well in the test went on to learn arithmetic (with math	Mathematics test Observation notes Interviews	Quantitative Cohort study (2 groups) Pre/post Experimental n=26 Control n=20 (conventional teaching methods)	Students in the experimental group were found to be superior both in mental arithmetic (including speed and accuracy) and in logical reasoning.

		games and word problems) while the others continued to play physical-knowledge games.			
Karnes [40] 2021 Germany	n=4 students Ages: 8-9 years 3rd grade elementary school students, Nord Rhine Westphalia	Game: Racetrack (game board). Duration: 3 x 20 min training sessions/week over 6 weeks.	Observations	Quantitative Cohort study (1 group) Pre/post/delayed (3 weeks after)	Substantial improvement in performance (accuracy and speed) in all students, with scores being maintained at 3-weeks post training in the math racetrack game. All students were accepting of the intervention, none of them commented negatively.
Liang [37] 2020 China	n=96 students Ages: 5-6 years Low SES preschool students at two locations; Central Kindergarten at Wangyuan Village in Xingqing District, and Huisiyuan Kindergarten in Xixia District	Number sense game: Rtl-based Mathematics test math intervention: self-made number cards, small bamboo baskets, beans, pills, etc. Phase 1 (month 1) - promote counting and number knowledge ('ordering digital card', 'splitting beans', and 'selecting the pill'). Phase 2 (month 2) - improve children's abilities in number knowledge and number operations ('taking cards according to rules', 'Loto transferring card', and 'Bingo filling in grids'). Phase 3 (month 3) - further implementation of interventions on counting, number knowledge, and number operations ('sprinkling buttons', 'throwing dice', 'card double-click battling', and 'refuelling the plane'). Duration: 2 x 15-30 minutes sessions, each week over three months, total of 24 sessions, in small groups.	Mathematics test	Quantitative Cohort study (3 groups) Pre/post (after each phase)/delayed test (2 months later) Experimental (low SES) n=31 Control (low SES) n=32 (Storybook reading) Reference (middle/high SES) n=33 (Storybook reading)	Significant improvement in number sense (counting, number knowledge, number operations) in the intervention group which almost caught up with the middle/high SES group after training. The intervention effects persisted for two months. Slowest rate of progress and significantly lower scores than the other two groups were found in the control group.
Markey [41] 2003 Australia	n=4 Ages: 11-12 years Students with hearing impairments at a regular elementary school	Games: make a match between the pictorial representation of a fraction and the appropriate language. Students were also required to compare fractions, match equivalent fractions, and work with fractions of a group. The entire program consisted of games and activities with minimal use of traditional "teacher talk-centred" methods. Duration: a total of 25h class time.	Mathematics test Observations/ Lesson transcripts	Qualitative	Students showed a good understanding and application of fractions and mathematical language, and gained some self-esteem.
Marshall [32] 2004 USA	N=45 students Urban elementary students enrolled in an after-school program	Students first used Pattern Blocks and the Stick Figures game to investigate attributes of objects and then explored classification further with the SET game. After these activities that were designed to develop classification skills, students explored classification combined with sequencing	Video recordings Student-produced artefacts Interview (students)	Qualitative	Students were able to construct their own, logically consistent, interpretations of the puzzle clues, as they used self-generated rules about alignment and orientation to construct meaning in ambiguous clues.

		using Logix puzzle cards (card game) for approximately 1 week. Duration: One 5 week unit/45 min/4 days a week.			
McFeetors [15] 2018 Canada	n=45 students n=3 teachers 5th and 6th grade students from Pollard school in an urban location in a western Canadian city	4 games: Gobblet Gobblers, Othello, Tic Tac Toe, and Go. Cycle 1 – explore the game, then develop and describe emerging strategies, 2 vs 2 students playing. Cycle 2 – create more effective strategies and more sophisticated justifications, 2 vs 2 students playing. Cycle 3 – refinement and defence of strategies, students to express themselves as experts, 1 vs 1 student playing. Duration: Once a week, for 1 h, over approximately three months.	Field notes Student record sheets Photos Interviews (students and teachers)	Qualitative	Through characteristics of interaction and continuity, students analysed moves, generalised toward strategies, and convincingly justified effective approaches through accepted structures of reasoning. Elaborating on reasoning as a process, results show that students can grow in their capability to reason through multiple experiences of developing convincing arguments in an authentic context.
Nisbet [60] 2009 Australia	n=58 students n=2 teachers Students at a Queensland Primary School in 2 combined 7th grade classes	Games: 4 x Dice games, 1 x Multiplication Bingo, 1 x Class activity with brown paper bags and pegs. In the implementation stage of the study, one of the two researchers taught the first lesson consisting of two games/activities to the combined class. A day or two later the lesson was repeated in individual classes by each teacher. Duration: 6 activities over an 8-day period.	Student surveys Interviews (students, teachers) Journal entries (teachers)	Mixed methods Quantitative part: Cohort study (1 group of two combined classes) Pre/post	Students: Significant short-term improvements in their enjoyment when learning about chance, less anxiety and worry when working on chance, greater motivation, and desire to learn more about chance in class, and an increased perception of the usefulness of chance in their lives. Teachers: High levels of student enthusiasm, enjoyment, and motivation, as well as challenge and competitiveness across all levels of ability.
Nizaruddin [57] 2017 Indonesia Conference paper	n=200 students Grade 7	‘Jirak’ is a traditional mathematics game. 2 groups compete. Questions and answers of different levels of difficulty were provided in a concealed envelope.	Mathematics tests Questionnaires	Quantitative Cohort study (2 groups) Experimental n=100 Control n=100 (traditional learning)	Higher levels of average student achievement and mathematical disposition in the ‘Jirak’ game group compared with the traditional learning group.
Prahmana [49] 2012 Indonesia	n=26 students Ages: 7-8 years n=1 teacher 3rd grade students at SD n=179 Palembang	Card game PT2B with picture cards and worksheets to record results. Groups of 4 students (2 + 2).	Video recordings Worksheets Field notes	Qualitative	Improved understanding of the basic concepts of multiplication. Improved ability to solve problems with a variety of strategies. Increased student motivation to learn multiplication.
Putra [53] 2011 Indonesia	n=27 students Ages: 6-8 years 1st grade primary school students at SDN 179 Palembang	Parrot game: The teacher started the activity by showing a colourful parrot puppet on her hand and telling the students that: This is a Parrot and he can say for instance 10. Then the teacher asked the	Classroom observations Interviews (students) Field notes Video recordings	Qualitative	While the students learnt number facts up to 10, the game engaged them and fostered active communication. The students build mathematical ideas that

		students: What number pairs can give the answer 10?			were compensation and commutativity.
Rajotte [46] 2016 Canada	n=119 students 3rd grade students from the Abitibi-Témiscamingue, Québec	Experimental 1: daily routines in mathematics (Sudoku, Chess, Find an intruder in a group of objects, Match replacing, Solving adaptation of Raven's matrices). Experimental 2: play mathematical games two hours per week. Duration: 2 months.	Mathematics test	Quantitative Cohort study (3 groups) Pre/post Experimental 1 n=48 Experimental 2 n=33 Control n=38 (no intervention)	Improved skills in solving problems specifically involving the meaning transformation of the addition field. Daily routines in mathematics, which involved playing games or solving different logical challenges, acted as an external component of school motivation. Improved introjected extrinsic motivation: Girls - daily routines that varied mathematical tasks every day and in boys – daily routines that involved mathematical games (Board games).
Singh [50] 2021 Malaysia	n=34 students Ages: 12-13 years n=5 teachers 'Secondary One' students from five classes at a public school in a district in Selangor, Malaysia	Math Zap Card Game: The main aim of this game was to get all the cards in the pack, and if it did not happen, the game went on. Students played in groups of 4-5 players. Duration: 12-15 sessions over 4 weeks.	Mental computation test Questionnaire Focus group interview (teachers)	Mixed methods Quantitative part: Cohort study (1 group of students) Pre/post test Qualitative part: Teacher interviews	Students: Improved student's ability to think quickly and perform mental computations (e.g., between fractions, decimals, and percentages). Playing the game evoked higher levels of alertness in students, increased mental and visual speed, and the ability to provide verbal responses. Students enjoyed playing the game and viewed it as an outstanding education tool. Teachers: the game enhanced the ability of students to perform mental computations, especially so in terms of matching the five concepts; they further concluded that students were having fun.
Skillen [44] 2018 Germany The rule counts	n=48 children Age: 6 years Children from 3 German Kindergartens	'100 house' – linear number board game, using two tokens and a die (a board with 100 numbers printed on it, a matrix 10 x 10, played similarly to 'Snakes and Ladders'). Group 1 – played according to the count-on rule. Group 2 – played according to the count-from-1 rule. Duration: 4 sessions of 20-30 min playing game and 2 sessions assessment playing the game over 6 weeks. The game was played with one child and one assessor.	Mathematical performance test	Quantitative Cohort study (2 groups) Pre/post/delayed (10 weeks after post-test) Group 1 n=24 Group 2 n=24	Significant and stable improvements in performance in the assessed mathematical competencies (early number strategies of count-on, count from 1). Children in the count-on condition displayed a greater benefit than children in the other group.
Van Putten [56] 2022	n=51 students Ages: 11-12 years	Game based worksheets: Students paired up and either completed the worksheets	Mathematical knowledge test Observation	Mixed methods Quantitative part: Cohort study (2	Improved academic achievements, student confidence, skills, and

South Africa	Students from a primary school in South Africa	together or competed. For the intervention, the teacher taught her classes as she normally would, with the addition of the pre-tests and post-tests. Mathematics topics covered: multiplication, nets of 3D-objects, symmetry, and division. Pre-tests for both groups every Monday before new content being taught. Post-test for control group each Friday. Post-test & Observation of experimental group each Friday. Duration: 4 weeks/1 topic per week.	during completion of post-test	groups) Pre/post Experimental n=28 (game-based worksheet format for post-test) Control n=23 (normal textbook format for post-test)	understanding in mathematics. The intervention had a particular positive impact on the topics of multiplication and division. Creating and using games in the classroom are beneficial, and accessible to any teacher.
Vetter [55] 2020 Australia	n=172 students Ages: 7-9 years 3rd grade students from 2 urban Australian schools	Physical Activity (PA) Program: shuttle run (10 min), a circuit (5 min) and paired relays using game props such as dominoes, number charts and worksheets (10 min); and a wrap-up 'recall' ball game (5 min). After the 30 min intervention, the students returned to their usual classes that focussed on other mathematics skills for the remaining 30 min. The classroom group completed 30 min of learning the same multiplication-tables as the Playground group whilst seated in the classroom. Three games, adapted bingo, number charts and adapted dominoes were provided. Duration: 1 year - 3 sessions/30 min/week.	Multiplication fact test NAPLAN test equivalent Accelerometers Shuttle run test Body Mass Index	Quantitative Cohort study (2 groups) Pre/post School A n=110 (first 2 terms of the year) School B n=62 (second 2 terms of the year)	Significantly greater improvement in learning mathematics multiplication tables in the playground compared to the classroom condition, however this did not translate into general numeracy scores. Participant fitness increased significantly more in the playground compared to the classroom. The playground condition also produced significantly greater step counts, moderate-vigorous and vigorous PA during the 30 min intervention. The intervention was similarly beneficial for boys and girls.
Vogt [47] 2018 Switzerland	N=329 children Ages: 5-6 years N=35 educators Children from kindergartens in the Canton of St. Gall, Switzerland	Training program: 'Mengen zählen Zahlen' (Quantities counting numbers). Game-based approach: card and board games - Halli Galli, Shut the Box, Lining up the Fives, More is More - comparing quantities, counting, number recognition and part-and-whole relationship. Duration: 24 units/30 min/over 8 weeks.	Mathematical competencies test Semi-structured problem-centred interviews (educators)	Mixed methods Quantitative part: Cohort study (3 groups) Pre/post Experimental (training program) n=111 students, n=12 educators Experimental (play-based intervention) n=91 children, n=11 educators Control (practice as usual) n=127 children, n=12 educators	Significantly higher learning outcome in quantity-number-competencies for the group of play-based mathematics compared to the traditional kindergarten, but no effects for the training programme group. Educators reported that the training program was mainly beneficial for children with very low competency, but that the play-based approach served all children, from low to high competency. Educators viewed the play-based approach more positively because it was more fun and less school-like.

White [61] 2019 USA	n=24 students 5th grade students from a public elementary school in the south-eastern United States	Game-based learning approach: Mathematical Day 1: assessment, Day 2: watch video, clarify vocabulary, play battleship. Day 3: identify at least fifteen points on a coordinate grid and write a creative story using the emojis at those grid points to describe their coordinate path in their Emojilicious Coordinate Story. Day 4: students rotated through a set of five stations including a Dice Game, Mission: Zombies, Connect Four, Finger Twister, and City Planner. Each of the stations asked students to use their knowledge of ordered pairs to think critically and develop a strategy for the particular activity. Day 5: assessment. Duration: 3 x 60 min sessions (across days 2-4).	Mathematical competencies tests Interviews Video recordings Field notes Surveys	Mixed methods Quantitative part: Cohort study (1 group) Pre/post	Significant improvements both in student's attitudes about mathematics and their achievement in ordered pairs. Increased growth mindset that fostered a positive work ethic. Increased openness and resilience to developing skills and concepts. Improved problem-solving skills, and student engagement. The game-based learning process allowed the students to work together to tackle complex, real world situations.
Young-Loveridge [38] 2004 New Zealand	n=106 children Ages: 5-6 years 1st grade students with low socio-economic status from 4 primary school in a NZ city	31 games and 47 books (number stories, rhymes, and games). Begin easy, then increase difficulty level. Children attended the intervention sessions in pairs. Duration: 35 x 30 min/over 7 weeks.	Individual task-based interviews	Quantitative Cohort study (2 groups) Pre / post / delayed / delayed test (6 & 15 months after intervention) Experimental n=23 Control n=83 (conventional teaching method)	Increased numeracy levels and significantly greater gains in numeracy for the children in the program compared with those in the contrast group. Once the intervention program ceased, the magnitude of these effects gradually diminished over time, but the benefits of participation in the program remained statistically significant for more than a year after the program finished.