8-21-2023

# Game-Based Learning in Elementary Mathematics

Sophia Greenfield
*Concordia University - Saint Paul*, dragers@csp.edu

**Game-Based Learning in Elementary Mathematics**

Sophia Greenfield

Concordia University, St. Paul

Master of Arts in Education - K-6 Education

ED 590: Research & Complete Capstone Cohort 303

Course Instructor: Dr. Oluwatoyin Akinde Fakuajo

Second Reader: Professor Kristin Blevins

August 13, 2023

## Dedication

This capstone paper is dedicated to Camp LuWiSoMo and my husband, Noah Greenfield. Thank you, camp, for providing me with a vast knowledge of games, which inspired me to research ways to apply these games in the classroom. Thank you, Noah, for your endless support and patience: staying up late with me, encouraging me to persevere, being a sounding board, and reminding me to take breaks. Thank you for listening to me and giving me more confidence throughout this research project.

**Acknowledgment**

First, I would like to thank my professor, Dr. Oluwatoyin Akinde Fakuajo, for providing valuable guidance in deciding on math as my topic of focus and for suggestions to create more clarity in this research study.

I am deeply grateful for my peer review team: Christina DeRungs, Angela Remily, Pheng Yang, and Jessica Nowacki Van Denheuvel for providing constructive feedback, having a great deal of patience, and giving a lot of support throughout the writing process.

I would like to extend my gratitude to Professor Matt Ryan, Pastor Reed Stockman, and my husband for helping me structure my initial literature review, which developed into the research study below. I also wish to thank my dad, Chris Drager, and Brainfuse for reading through my initial literature review.

## Table of Contents

**Abstract**

This paper analyzed 15 primary, peer-reviewed research articles about how to integrate game-based learning in elementary mathematics to increase conceptual understanding. The purpose of this paper was to inform teachers about how to integrate digital and traditional games, including factors to enhance effective implementation, in a way that increased conceptual understanding. Key factors were gleaned from the articles that had a significant impact on the effectiveness of game-based learning. In Chapter Two, traditional and digital games were divided into two sections to analyze the benefits and drawbacks of each method. These benefits and drawbacks were compared in the Appendices to create universal factors of both traditional and digital game-based learning. These factors included educational context, key characteristics, and the teacher's role. Research had multiple gaps within the literature that could be filled to enhance the credibility and further validate game-based learning as a viable supplemental tool to instruction in elementary mathematics.

*Keywords:* conceptual understanding, digital game-based learning (DGBL), game-based learning (GBL), gamified, traditional game-based learning (TGBL), traditional instruction

Game-Based Learning in Elementary Mathematics

## Chapter One: Introduction

Game-based learning (GBL) has grown as an instructional tool within the classroom. Game-based learning branched into two effective methods: traditional game-based learning (TGBL) and digital game-based learning (DGBL). Electronic technology use in the classroom has increased in the past century, starting with the radio in the 1920s (Halper, 2021). According to Takeuchi and Vaala (2014), 74% of teachers integrated digital game-based learning in the classroom (Noffisinger, 2019; Bouchrika, 2023). During the COVID-19 pandemic, many students had to adapt to learning online. In 2021, the United States made up 26% of all global revenue of digital game-based learning and was projected to increase revenue to 31% by 2026 (Adkins, 2021). The search engine generator presented a limited number of peer-reviewed research sources that were published in the last five years about traditional game-based learning in elementary mathematics. Therefore, this study aimed to uncover integration methods of digital and traditional games that can be effective for learning and teaching elementary mathematics to increase conceptual understanding.

### Scope of Research

Game-based learning (GBL) could be implemented into any grade or subject; however, this analysis of existing literature explored integrating traditional and digital game-based learning into mathematics for kindergarten through sixth grade. Both methods had been studied by scholars to measure an increase or decrease in students' conceptual understanding, as outlined in Chapter Two. Chapter Two separated traditional and digital game-based learning to explore the benefits and drawbacks of each method for implementation into elementary mathematics. Then, the benefits and drawbacks were analyzed and outlined in both Appendices to form conclusions about both traditional and digital game-based learning. These conclusions were summarized in Chapter Three to inform teachers about the best game-based learning integration methods to enhance students’ conceptual understanding of mathematics.

From the game-based literature, three factors to consider for more effective integration emerged: educational context, key characteristics, and the teacher’s role. An in-depth review or inclusion of game design features that were effective for game-based learning in elementary mathematics was beyond the scope of this research. Rather, this study revealed key factors within game-based literature that increased students’ conceptual understanding and impacted the integration of game-based learning as a supplemental tool for instruction. Additionally, while the research focused on increasing conceptual understanding, it did not include a review of how fast students gained this understanding. All of the studies analyzed focused on identifying a change in posttest scores to evaluate a difference between traditional instruction and game-based learning rather than assessing students during the experiment to measure their progress.

**Importance to the Field of Education**

Teachers used game-based learning as a supplemental tool to expand conceptual understanding in online or play-based contexts. The Entertainment Software Association (2022) stated that over 70% of children in the United States play video games at least once a week. Children were born with the innate ability to play, and many theorists had studied the correlation between play and learning (Plass et al., 2015; Piaget, 1962; Vygotsky, 1978). According to Nasir et al. (2020), Gen Z and Alpha (born 1995 - 2025) preferred interactive lessons, collaboration, and challenges in activities rather than traditional instruction.

Mathematical concepts have been applied in everyday life, unbeknownst to many (Syahrial et al., 2020). Children were able to reapply prior knowledge to increase their conceptual understanding when games were integrated into elementary mathematics. Furthermore, students remembered knowledge and skills gained in game-based learning longer than in other learning methods (Avdiu, 2020; Bang et al., 2022). Therefore, digital or traditional games were effective supplemental tools as they made education more interactive and student-centered, as well as increased conceptual understanding.

Game-based learning was beneficial to students and educators. Beyond teachers' instructional methods expanding, their role as moderators and guides increased. Based on the branch of game-based learning integrated, educators were presented with more or fewer opportunities to invest in creating and moderating instruction (Avdiu, 2020). Teachers gave students immediate feedback and used game-based learning as a supplemental tool for enhancing instruction.

## Research Question

Throughout the Master of Arts in Teaching program at Concordia University Saint Paul, each course has pointed to the program’s essential question: In light of what we know about how people learn, how shall we best teach? The program directed attention to various subjects and teaching methods that enhanced learning and met students' academic needs. After carefully considering how educators could teach, a more specific question arose as an area of personal and professional exploration, which was asked in this research paper. In light of what we know about how children learn, how shall we best integrate game-based learning in elementary mathematics to increase students’ conceptual understanding?

## Definition of Terms

The definition of terms below provided clarity throughout this research. Game-based learning was an umbrella term for both traditional and digital games (Plass et al., 2015). GBL and its two branches were defined separately and abbreviated with acronyms for concision. Each definition was paraphrased from the articles concerning game-based learning and elementary mathematics.

### *Conceptual Understanding*

Conceptual understanding was defined as having a deep comprehension of concepts (Nahdi & Jatisunda, 2020). “When students have truly mastered a concept, they should be able to show all the detailed steps in a process, explain why those steps occur, and connect the process to related concepts” (Molina, 2014, p. 3). Some schools focused on procedural knowledge as the first step, understanding the rules of mathematics (Nahdi & Jatisunda, 2020). Using conceptual understanding as the foundational step in mathematics instruction aided in teaching students more effective or faster methods of completing the same expressions (Molina, 2014; Nahdi & Jatisunda, 2020).

***Digital Game-Based Learning (DGBL)***

Digital game-based learning was defined as utilizing technological games (i.e., electronic games) during instruction (Çelik, 2019). Mark Prensky was said to be the person who coined the term (Matic et al., 2023). Digital game-based learning was designed as a supplemental teaching strategy to enhance learning (Bustamante et al., 2022; Matic et al., 2023).

***Game-Based Learning (GBL)***

Game-based learning was divided into two main game categories: traditional games and digital games. It was defined as integrating games into the subject matter (Avdiu, 2020; Çelik, 2019). Game-based learning implied the use of digital games, but this was sometimes misleading (Plass et al., 2015). GBL was more of an umbrella term for any type of game (Plass et al., 2015). This teaching strategy was best implemented as a supplementary tool to instruction (Bustamante et al., 2022). In other words, Game-based learning was the means to meet the end goal and both the content and activities needed to have a balance in the classroom (Plass et al., 2015).

***Gamified***

Gamified was described as any digital game feature that made “the game more aesthetically pleasing rather than just the presence of math expressions” (Hulse et al., 2019, p. 430). Gamified features of a game include competitions, collections, rankings, non-player characters, or coins and badges (Chen & Zhao, 2022). This term was only used to describe applications, features, designs, or versions of a game in DGBL studies, specifically Hulse et al. (2019) and Gresalfi et al. (2017).

### *Traditional Game-Based Learning (TGBL)*

Within the field, the word traditional was sometimes referred to as classic games such as hopscotch, kickball, or Go Fish in the field. In this research, traditional games were considered "non-digital" games (Russo et al., 2023, p. 3). The word traditional was used sparingly within the research field. Traditional game-based learning was not an official term within the field of research. However, traditional games and the term traditional game-based learning (TGBL) have been used within this study to eliminate any assumptions and emphasize the non-digital component of the games being played (Plass et al., 2015).

### *Traditional Instruction*

Traditional instruction was a familiar strategy many students had experienced at least once in their educational journey. It was defined as "existing instruction methods" (Çelik, 2019, p. 6). Common tools for traditional instruction in the literature review included lectures, a teacher handbook, and slideshows (Zhang, 2020). Learners are not typically engaged in the instructional process beyond receiving instruction and responding to questions (Plass et al., 2015).

## Summary

According to the Entertainment Software Association (2022), 70% of children in the United States play video games once a week. Children understand and enjoy games. Scholars studied play and learning to enhance students' experiences in the classroom (Plass et al., 2015). Game-based learning emerged as a teaching method that included two branches: traditional and digital games. The term traditional game was not widely used in the field, so traditional games and traditional game-based learning (TGBL) were adopted to further clarify what branch of GBL was mentioned. Other adopted terms include conceptual understanding, digital game-based learning, game-based learning, gamified, and traditional instruction. Many teachers embraced the integration of digital game-based learning. Yet, research about traditional game-based learning held significant insights into factors to consider to increase effective integration and conceptual understanding of elementary mathematics.

In Chapter Two, traditional games and digital games were divided into two sections to analyze the benefits and drawbacks of each method. Comparing findings from both traditional and digital game-based learning provided a fuller picture of the best methods to integrate game-based learning in the elementary mathematics classroom. These comparisons will be a guide in addressing the research question. In light of what we know about how children learn, how shall we best integrate game-based learning in elementary mathematics to increase students' conceptual understanding?

# Chapter Two: Literature Review

Available literature was analyzed within the game-based learning (GBL) field of elementary mathematics. Fifteen peer-reviewed primary research articles were selected. Qualitative, quantitative, and mixed-methods studies were included to diversify the literature. Most of the researchers from each section measured the impact game-based learning had on conceptual understanding as opposed to traditional learning. Two researchers interviewed teachers about the best methods and their perspectives on factors that were important to consider for implementation. A few more researchers measured how effective a game was to meet learning objectives. The literature review was divided into two sections: traditional game-based learning (TGBL) and digital game-based learning (DGBL). This division provided an in-depth review of how each study integrated game-based learning. The benefits and drawbacks of traditional and digital GBL were included to draw out universal commonalities between both methods as it informed educators of answers to the research question. In light of what we know about how children learn, how shall we best integrate game-based learning in elementary mathematics to increase students' conceptual understanding?

## Traditional Game-Based Learning

Traditional game-based learning (TGBL), an instructional method, integrated non-digital games as a supplement to instruction. Throughout the literature review, seven primary sources were analyzed to discover what games were utilized and how educators integrated the games into elementary mathematics. Games integrated include Go Fish, bingo, memory cards, hopscotch, fraction ball, hide and seek, Numeranto, choc-chip cookies 21, get out of my house, and more. Teachers integrated the games through field trips, blended learning with traditional learning, free play, and blended into physical education. After summarizing how each study integrated the games into learning, the studies were analyzed and compared to uncover common benefits and drawbacks of integrating traditional games into the classroom. Some results included noting the educational context, important characteristics of games that impact effective integration, and the teacher's roles while using either branch of GBL.

### ***Integrated TGBL***

Çelik (2019) was fascinated with teaching in nature. The researcher conducted a mixed-methods study to discover which method of learning was most effective for teaching geometry in nature. Çelik (2019) developed a pretest and posttest using the geometry success test, which quizzed the students on 10 geometry outcomes from third-grade math standards. After taking the posttest, students were interviewed about their experiences. One hundred and one third-grade students from three public schools in Anatolia, Turkey, were randomly assigned to groups. Group A used the modeling technique to learn. Group B focused on collaborative learning. Group C used game-based learning, and the control group used traditional learning. Students experienced their learning method for a total of 24 hours over six days. Each group attended the same field trips to parks to learn the same geometry lessons, using a blended learning approach. In addition to traditional learning, group C played a new game every day. The games were rolling a cube to find similarities and differences in the shape and surface, using a string to find line segments in nature, playing hide and seek in tents and caves to learn shapes, throwing balls to learn about the angles of their arms and body, counting how many edges and corners were on shapes in paintings, and playing a "symmetry" game. Researchers concluded that group C did not perform better than traditional learning, but being in nature made the lessons more interesting. This experiment had three main limitations. The first was the lack of detail in what activities were played and how they related to the content. From the information provided and the implications Çelik (2019) determined, the games could not be implemented in any educational context to effectively meet objectives and increase learning. Another limitation was the small sample size and the need for more grade levels of students to be involved as a means to further generalize the information (Çelik, 2019).

Similar to Çelik (2019), Bustamante et al. (2022) observed game-based learning outside. The researchers created the game fraction ball to meet math standards so that the game could be played during free play, recess, P.E., or in blended instruction. They created two experiments: a pilot experiment and an efficacy experiment. Bustamante et al. (2022) used quantitative methods to measure the impact the game had on students' conceptual learning of fractions and decimals. In the pilot experiment, 69 fifth and sixth-grade students participated. Students were given a pretest based on their averages. They were separated by gender, above average, and below average standardized scores. Half of the students in each separation were randomly assigned to regular P.E. and the other half played fraction ball. Students, in groups of 16, played four times over two weeks. Teachers monitored and refereed the game. After two weeks, the students were given a timed and untimed posttest to measure their conceptual understanding. The teachers provided feedback for necessary changes for the second experiment. The second experiment was conducted one school year later. Mini-games were added to the fraction ball game, such as a ghost number line, debriefing activities, and calling out the number closest to the individual -- on or off the court. These additions were intended to increase opportunities to learn more fraction and decimal standards. In the second experiment, 160 students from fourth- through sixth grade were observed. Only seven students from this new sample participated in the pilot study a year prior. Students were split into two groups to participate in regular P.E. or play fraction ball for six 50-minute sessions over three weeks. All students received traditional instruction in mathematics in class. Students received a pretest and a posttest. Results indicated that students who played fraction ball had higher conceptual understanding results than the control group. The modifications from the pilot study for the second study positively impacted the conceptual understanding of rational numbers and arithmetic. Bustamante et al. (2022) included similar limitations to Çelik (2019) that did not influence this study but could influence future implementation of fraction ball. These limitations included the need to consider the setting, the population of students, the region or country in which the study would implement the game, and if more math content would be integrated. Another limitation was the complexity of the game design and the requirements needed. An additional study would be recommended to evaluate how the game could adapt in more public settings (Bustamante et al., 2022).

Elofsson et al. (2016) moved game-based learning inside. They conducted a quantitative study where they divided 114 children, aged five, into four groups. Over three weeks, students played their assigned game for six 10-minute sessions as interventions in unoccupied rooms with the researchers. The assigned games were linear, circular, or nonlinear. The linear and circular games involved rolling dice, moving a token to the corresponding Arabic number on the chart, and naming the number out loud. The nonlinear games included memory games, bingo, and Go Fish. Researchers measured four numeracy tasks: number line estimation, counting, naming Arabic numbers, and arithmetic calculation. As a result, the nonlinear games improved counting skills, while the circular game improved the ability to recognize Arabic numbers. Elofsson et al. (2016) found the retention impact to be undecided due to students' limited time with the games and their young age. Another limitation of retention was the controlled environment students participated in rather than a natural classroom setting (Elofsson et al., 2016).

Another study that integrated games through intervention was conducted by Nasir et al. (2020). However, Nasir et al. (2020) were the only TGBL study to focus on card games. Nasir et al. (2020) conducted a mixed-methods study by performing a pretest, posttest, and interview of students' perspectives. Seventy children were included in the study. Over six weeks, students played the Numeranto card game to practice numeracy skills. One of the limitations Nasir et al. (2020) had been the lack of information on how much time students spent playing the games. As a result, students noted a reduced fear of failure, an increased attempt to answer questions, and they felt they had learned numbers. The researchers also concluded that students were more motivated to learn, communicated math concepts more clearly, and had higher math achievement. Despite the positive results, Nasir et al. (2020) had an additional limitation, a small sample size, that could have impacted the results.

Shifting from observing students, in three separate studies, teachers were interviewed about traditional games and their perspectives on game-based learning (Syahrial et al., 2020; Russo et al., 2023; Avdiu, 2020). Syahrial et al. (2020) conducted a mixed-methods study to determine if the teachers knew about the classic Indonesian game Engklek, also known as hopscotch, and if it could be integrated into elementary mathematics. Thirty-four elementary school teachers were interviewed. Syahrial et al. (2020) found that 52.9% of teachers were familiar with the game, but many were unaware of implementing Engklek into learning. The researchers illustrated how to play Engklek and that it could be integrated to teach numeracy and shapes. Some of the limitations of the study were the small sample size and the lack of open-ended questions to give more details about the teachers' perspectives on traditional games and Engklek.

Russo et al. (2023), another set of researchers who interviewed teachers, conducted a mixed-methods study and used an online questionnaire as their primary tool for measuring game values. The researchers selected a convenience sample of 119 participants. Of the number of participants, 68% of the population were primary teachers. This study also recorded that 83% of the participants were from Australia. Participants could pick any game they knew to work in a mathematics classroom. However, the fourth researcher directed participants to his YouTube channel, which contained directions for about 100 math games as an option. The survey used a Likert Scale of five points followed by an open-ended prompt to explain their answer. The purpose of the survey was to assess the extent to which the educator viewed a game as effective in education (Russo et al., 2023). Twenty questions were asked in the survey, which covered six characteristics of educationally rich mathematical games. The characteristics were student engagement, skills and chance, math centrality, modifiability for learning and teaching, home-school connections, and games into investigations. The teachers identified a total of 53 games that were valuable to them. Two games, choc-chip cookies 21 and get out of my house, were the only games nominated by more than seven participants (Russo et al., 2023;

Minas, 2023; Minas, 2020). The experiment did not indicate how teachers integrated games into the results because the participants did not have to lead a game in the classroom to include it in the survey. Results indicated that teachers sought games that were modifiable for teaching and learning, brought new challenges to students, and were enjoyable to play. The limitations of this study included the use of a convenience sample and the fact that the teachers did not have firsthand experience with the games. Another limitation was the unlimited number of games that could have been chosen, which provided broad results and prevented the researchers from identifying the characteristics most strongly related to game usage. There was also no indication as to which grade levels the teachers used the games for (Russo et al., 2023).

Similar to Russo et al. (2023), Avdiu (2020) was also interested in interviewing teachers about games they used to teach. However, Avdiu (2020) was more selective in their population. The researcher conducted a qualitative study to interview 24 elementary-grade teachers from Austria. Unlike Russo et al. (2023), the interviewees were questioned in person and were observed over two months (Avdiu, 2020). While the interview included the integration of games into all subjects, some mathematics games to note were tangrams, Lego building, counting with fingers and sticks, and the clothesline game. The teachers in Avdiu's study (2020) either allowed free choice of the game to support reflection and conceptual understanding or adapted the game in the lesson to meet as many curriculum objectives as possible. Teachers stated they struggle to include games, meet students' needs, and keep students interested in the games. One of the potential limitations of this study was that the researchers only interviewed teachers but not any students or paraprofessionals.

### ***Benefits of TGBL***

In light of what is known about how children learn, how shall we best integrate game-based learning into elementary mathematics to increase conceptual understanding? Appendix A: Scope of the Research identified two of the studies related to TGBL that used blended instruction (Çelik, 2019; Bustamante et al., 2022). Elofsson et al. (2016) and Nasir et al. (2020)

integrated the games as interventions for students. However, the latter study did not provide details about how the game was integrated into the classroom. In Avdiu (2020), the interviewed teachers stated that games were best integrated as a free choice activity or merged with as many subjects as possible to increase the number of objectives met. Bustamante et al. (2022) also integrated the game fraction ball during free time, in P.E., as an intervention, and as a blended learning approach with traditional instruction. The only two studies that did not identify how games were integrated into the classroom or at home were Syahrial et al. (2020) and Russo et al. (2023).

All of the TGBL studies included in this literature review identified enjoyment of the games as an important characteristic for considering the integration of a game (Çelik, 2019; Bustamante et al., 2022; Elofsson et al., 2016; Russo et al., 2023; Avdiu, 2020; Syahrial et al., 2020; Nasir et al., 2020). In Çelik (2019), Bustamante et al. (2022), and Nasir et al.'s (2020) studies, every student was interviewed and asked specific, open-ended questions to discover what factors were most influential to students' enjoyment of the games as well as learning and retention of mathematical concepts. The physical environment attributed to the lessons being more memorable and enjoyable (Çelik, 2019; Bustamante et al., 2022). Being outdoors was memorable for many students, but the simple opportunity to explore learning in an engaging and interactive way motivated students to take responsibility for their learning and increased their conceptual understanding (Çelik, 2019; Bustamante et al., 2022; Nasir et al., 2020; Elofsson et al., 2016).

Russo et al. (2023), Syahrial et al. (2020), and Avdiu (2020) focused on the educator's perspectives on how to integrate traditional games and the implications for effective integration. Participants from all three studies agreed that the students' enjoyment was an important characteristic in determining game integration (Russo et al., 2023; Syahrial et al., 2020; Avdiu, 2020). Additionally, games that were motivating and modifiable were also important aspects. Modifiability was key to integrating a traditional game because the teacher could better align the games to meet student's academic needs, the common core standards, and instruction while assessing the time and location to play (Russo et al., 2023; Bustamante et al., 2022; Çelik, 2019; Avdiu, 2020). Bustamante et al. (2022) illustrated modifiability by changing game rules and completing two experiments. By adjusting the game rules to include more mini-games, students were provided more opportunities to practice fractions and decimals, thus meeting more learning objectives that were not met in the pilot experiment (Bustamante et al., 2022).

Russo et al. (2023) and teachers disagreed about whether math centrality was the most important theme for integrating game-based learning into the mathematics classroom. Math was not as important as other characteristics from the educators' perspectives. However, the researchers asserted that mathematics was the most influential characteristic for implementing into the intended subject lesson (Russo et al., 2023). All TGBL studies maintained that math centrality was vital. Without this consideration, teachers would not meet learning objectives or effectively increase students' conceptual understanding, as seen in some of Çelik's activities (2019). By placing math as a central theme in the games, the teachers could focus on aligning the games with the lesson objectives to enrich the lessons and use GBL as supplementary tools (Avdiu, 2020; Russo et al., 2023).

Not only was TGBL beneficial to students' learning, but it was also beneficial to the educators' roles (Bustamante et al., 2022; Avdiu, 2020; Nasir et al., 2020). While students played, the teacher acted as a moderator and guide. The teachers were able to become more involved in actively creating learning experiences and facilitating learning processes (Avdiu, 2020). In Bustamante et al. (2022), the teachers had the option to freeze the fraction ball game to play mini-games that incorporated more exposure to mathematical concepts. Due to the increased investment teachers gave as moderators, students viewed their educators as "more supportive, approachable, and interested" (Nasir et al., 2020, p. 468).

### ***Drawbacks of TGBL***

Based on reviewing the seven TGBL sources, teachers were interested in integrating TGBL in their classrooms (Russo et al., 2023). According to Syahrial et al. (2020) and Russo et al. (2023), some government systems encouraged more prescriptive curriculum for teachers to develop lessons that met their students' needs and were better aligned with children's everyday activities, such as play, to learn and apply math concepts. Avdiu (2020) and Syahrial et al. (2020) noticed that educators struggled to integrate traditional games into learning due to the set curriculum, homework and worksheet requirements, and time constraints for each lesson. A solution teachers used was to insert games through blended learning, free choice, field trips, or integrating two classes (Avdiu, 2020; Çelik, 2019; Bustamante et al., 2022).

TGBL could be effective if implemented with caution. Some factors hindered the positive impact TGBL had on increasing conceptual understanding. One factor was that games could not be integrated as a one-size-fits-all approach (Çelik, 2019; Elofsson et al., 2016). Elofsson et al. (2016) demonstrated that intervention was an appropriate context for integrating TGBL. Yet, the researchers acknowledged that changing location from an isolated room to a less controlled environment could change the impact the game had on learning. According to Çelik (2019) and Bustamante et al. (2022), games were best integrated as supplemental tools to enhance learning and assessment, not primary teaching methods. The type of game had to be put into consideration before they were implemented. While games used in the studies were evaluated as appropriate for the environment, space, and timeframe, not all games aligned with the learning objectives and, as a result, became detrimental to students' learning (Çelik, 2019).

Çelik (2019) demonstrated that TGBL was equally effective as traditional learning in increasing conceptual understanding, whereas Bustamante et al. (2022) discovered TGBL to be more effective than traditional instruction. Çelik's results indicated little change in scores from the game-based learning group partly because the group had high pretest scores, which resulted in a less significant change in the posttest than other experiment groups (2019).

However, the other studies alluded to the effectiveness of TGBL based on students' enjoyment and increased attention span for learning (Elofsson et al., 2016; Avdiu, 2020; Syahrial et al., 2020). Digital game-based learning (DGBL) uncovered more evidence for increasing conceptual understanding and effective implementation.

## Digital Game-Based Learning

Throughout the literature review, eight primary sources were analyzed to discover what digital games were utilized and integrated into the elementary mathematics classroom. Games integrated included Semideus School, Motion Math, Slice Fractions, Math-Island, My Math Academy, Curse Reverse, Agrinautica, Creature Caverns, and more. Teachers integrated the games through blended learning with traditional learning, free play, and station work. Summaries were created for how games were integrated into learning for each study. Common benefits and drawbacks of DGBL were also analyzed and contrasted between articles. The most noteworthy of these were the educational context, key characteristics for successful integration, and the teacher's roles.

### *Integrated DGBL*

Bang et al. (2022) used a mixed-methods approach to measure student outcomes and teachers' responses to implementing the My Math Academy digital program in the classroom. A total of 954 elementary students from southern California were included in the study. Over half, 523 students, were in kindergarten, 406 students were in first grade, and 25 students were in second grade. Even though the study was intended to span the spring semester, the experiment was delayed until February because the teachers were on strike. This became one of the limitations of this study. Twenty-one teachers were randomly assigned to integrate My Math Academy, while 20 were chosen to continue with traditional math instruction. The teachers that were in the control group attempted to integrate other programs that mimicked My Math Academy, such as IXL. Bang et al. (2022) noted this as a limitation because it may have skewed the results of how well My Math Academy worked compared to traditional instruction.

The teachers who used My Math Academy participated in 20 minutes of traditional instruction and then integrated the program for 20 minutes. Teachers either allowed students to play whatever games they wanted from the program during individual work time or had students work in groups of five at stations to play My Math Academy. Bang et al. (2022) demonstrated the effectiveness My Math Academy had on students because the youngest students had the most growth on the hardest skills to achieve. Overall, students who used My Math Academy indicated significant improvement in math skills and conceptual understanding (Bang et al., 2022).

Similarly, the next study used blended learning but controlled the traditional learning material and the games. The researchers created PowerPoint presentations and asked teachers to follow their teacher's handbook to teach traditional instruction (Zhang et al., 2020). The applications were opened before handing the students the tablet and split the classroom into two groups. These steps prevented students from finding the game name, playing it at home, and reduced the possibility of students realizing two different games were being played. Zhang et al. (2020) conducted a quantitative study where they observed 65 third-grade students from one primary school in Beijing who had access to iPads. One group played Slice Fractions, and the other played Motion Math. Students were monitored for six class periods. They received 120 minutes of game time and instruction, while the control group received 240 minutes of traditional learning. The researchers administered a pretest, posttest, and transfer test, which was given three days after the posttest. Significant improvement in conceptualizing mathematical concepts was not found in the posttest, but the students demonstrated their retention of concepts learned from the games in the transfer test. Zhang et al. (2020) noted that the lack of a pretest before the transfer test could have changed the results. Additionally, the study included a small sample size and did not have a third experimental group playing both games together, which could have changed the impact of conceptual understanding.

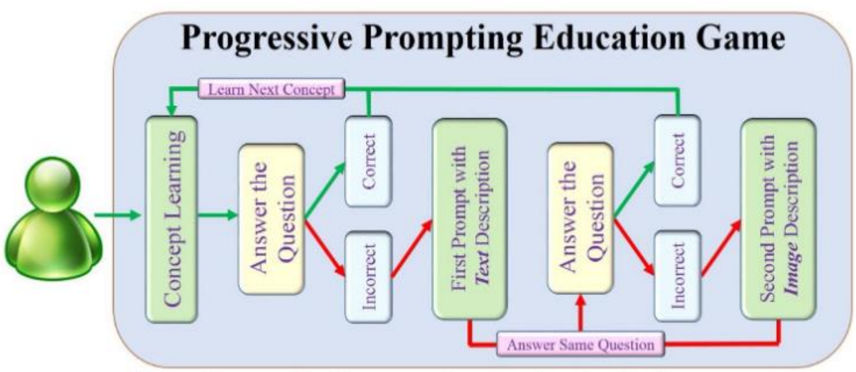
While Bang et al. (2022) and Zhang et al. (2020) integrated games as additional practice with the content students learned, Engledowl et al. (2021) took a different approach by weaving the games into the lesson. In this quantitative study, the researchers measured differences in their sample's conceptual understanding of early algebra knowledge and big ideas as a result of the three game-based lessons taught (Engledowl et al., 2021). The researchers used 457 students in fourth- and fifth grade from the southern United States. The students completed a pre-assessment one month before the experiment and a post-assessment two weeks after the experiment. The teachers attended two workshops to learn how to implement the games into instruction. Then, they were given two weeks to write three lessons integrating the intervention. The lessons from mathsnacks.org all followed a similar structure of blended learning that teachers followed: 20-30 minutes of undirected gameplay, 30 minutes of inquiry-based learning and small group discussion, and 20-30 minutes of gameplay. In the experiment, students played a new game each day that aligned with early algebra concepts: writing and interpreting expressions as well as expressing patterns and relationships between quantities. One game was played in each lesson: Agrinautica, Curse Reverse, and Creature Caverns (Math Snacks Team, 2023). As a result, students' conceptual understanding increased significantly from the use of blended, inquiry-based learning with digital games. One of the limitations Engledowl et al. (2021) noted was the short intervention time students had (60-90 minutes). If the intervention was longer, there may have been an increase in conceptual understanding.

Kiili et al. (2018) did not test the impact of integrating DGBL on student achievement. Instead, the researchers used a quantitative method to measure the impact the Semideus School application had on student mathematical achievements in learning concept areas. They investigated general "conceptual knowledge of rational numbers" and then, more specifically, the tasks of estimation, ordering, density and comparison (Kiili et al., 2018, p. 15). Five classes of fourth-graders in Finland were evaluated. Students were observed over four weeks for five 30-minute interaction sessions. The overall average play time was 110 minutes. Each class received lessons on rational numbers before the study began but did not receive additional lessons during the study. Results indicated that the researchers' first hypothesis was correct, and the student's conceptual understanding saw a significant improvement. Their second hypothesis was only half-proven because, while estimation and ordering tasks saw improvement, density and comparison tasks were stagnant. Additionally, the in-game metrics supported learning assessment for students by giving them feedback, which was also accessible to the teachers. This accessibility created implications that, if this study was measuring the impact of GBL, then teachers could use Semideus School to assess and predict students' "conceptual knowledge of rational numbers" as well as more accurately modify the curriculum to meet students' academic needs (Kiili et al., 2018, p. 25). There were three main limitations of this study. The first was the lack of a long-term transfer test. The second limitation was that the researchers did not have access to student-specific scores, which meant they could not determine if the high or low-achieving students progressed more than the other group. The final limitation was that a majority of the students were high achieving, which may have skewed the data.

Although Kiili et al. (2018) did not directly study the impact their game had on the teacher's roles, Yang et al. (2018) conducted a quantitative study that focused on feedback from the software they created, which led to implications for the teacher's role as moderator and guide. Yang et al. (2018) measured the impact two-step progressive prompting in games had on students' learning achievement, self-efficacy, and mathematics achievement. The researchers created a computer game called Kingdom of Addition and Subtraction. This game was designed to have students walk through a narrative about a warrior saving the town from being frozen by solving two-step addition and subtraction problems to find the antidote. Fifty-eight students in grade two from Taiwan made up the sample size. Students were given a pretest to measure math learning achievement and self-efficacy. Then, students attended three lessons, for 120 minutes total, that taught two-step addition and subtraction. Next, all the students played the game for a total of 90 minutes, but only 30 students received the Two-Step Progressive Prompting strategy. Figure 1 illustrated how students encountered the strategy in the experimental group. Finally, the students took a posttest to evaluate their progress. As a result, students who used the progressive prompting had significantly higher math achievement scores post-assessment. Additionally, students with low mathematics self-efficacy who also received prompting indicated no difference in learning achievement. After the study, the researchers allowed the students to try both versions of the Kingdom of Addition and Subtraction game. They did not have a preference for either version. This study demonstrated the impact of the software providing students with constructive feedback without the teacher present. Although not explicitly stated, the absence of the teacher providing feedback became a limitation for the teacher to be involved in the student’s learning processes, as seen in TGBL studies noted in Appendix B (Bustamante et al., 2022; Avdiu, 2020; Nasir et al., 2020). Other limitations included the small sample size and the short time students had with the game (90 minutes) (Yang et al., 2018).

**Figure 1**

*Two-Step Progressive Prompting Steps Description*




As Kiili et al. (2018) and Yang et al. (2018) studied specific characteristics that made DGBL more effective for integration, the next two studies focused on whether a gamified versus non-gamified (i.e., worksheet-like) design was more effective at improving conceptual understanding. Hulse et al. (2019) conducted a quantitative study to measure observable changes in their samples’ conceptual understanding of mathematics between a gamified and non-gamified design of the From Here to There! (FH2T) game. The researchers observed whether student’s improvement of conceptual understanding in high and low-knowledge students could be predicted based on their progress in the application. A total of 185 students in second grade from Massachusetts were included in the study. Students took a pretest aligned with the second-grade Common Core math standards and assessed their prior knowledge. Students were randomly assigned to play either the gamified or non-gamified version. Then, they played FH2T during mathematics class for 20 minutes each day over the course of four days. The researchers concluded that students who used the gamified version outperformed the group that used the non-gamified design in terms of conceptual understanding. Additionally, researchers found that they could predict students' conceptual understanding based on their progress in the game. One limitation that was suggested for future studies was to diversify the sample population (Hulse et al., 2019).

Gresalfi et al. study (2017) resembled Hulse et al. (2019) because both measured the impact worksheet-like versus gamified features had on students' learning. However, Gresalfi et al.'s study (2017) conducted a mixed-methods study that used five different games. Two games used gamified features, Slice Fractions and Motion Math, and the other three games had worksheet-like features, Tiny Fractions, Sort Fractions, and Jungle Fractions. For the study, the researchers organized interviews with students and administered tests to measure the impact of the students’ learning. The interviewers asked students what they had learned and if they enjoyed the game. The tests measured which style of the game had a greater impact on how much the students learned about fractions. Students were given a pretest and were evaluated on their ability to compare fractions, understand the value of a shaded area, translate the shaded area into a fraction, and correct another student’s incorrect answer with reasoning and explanation. Students were randomly assigned to either game style and given one hour each day for three days to play. Students were observed in class, their activities were videotaped, and they were interviewed one-on-one after playing the games. Then, students completed the posttest, which was the same as the pretest, and answered a questionnaire about their experiences. Researchers concluded that many students used correct terminology and made accurate connections to math concepts regardless of the game design. While students were more drawn to the gamified designs, the gamified and worksheet-like applications had a similar impact on increasing students' conceptual understanding. Gresalfi et al. (2017) noted limitations such as the short time frame (one hour), the novelty of the games, and the fact that the experiment broke the students' normal routine at school, which could have been factors that influenced students to prefer the gamified version.

In contrast to Gresalfi et al. (2017), comparing their five math games, Yeh et al. (2019) was a group that created a single in-depth and complex math game, Math-Island. Yeh et al. (2019) were researchers who conducted a mixed-methods study over two years that measured the effectiveness Math-Island had on students' conceptual understanding, problem-solving skills, calculating skills, and interest in mathematics for low-achieving students. From June 2013 to June 2015, 340 second-graders from two schools in Taiwan participated in the study. From one school, 215 students were assigned to use Math-Island in school as learning material and assigned as homework. The other school had 125 students participate in traditional learning as the control group. Before the first semester, the experiment group attended a three-week training workshop to learn the basics of the tablets and Math-Island game. Students were given a pretest and posttest based on second-grade math standards to complete and evaluate their progress. During the two years, the experimental group was given 344 tasks to complete in the game. The students were interviewed after the experiment to determine their interest in mathematics and the Math-Island game. Teachers were also interviewed on their perspective of how Math-Island improved students' attitudes towards mathematics. As a result, students who played Math-Island applied arithmetic better than those who did not use Math-Island, low achieving students had similar interest levels to the entire sample -- posttest -- and teachers saw the benefit to integrating DGBL in the classroom because it did not disrupt traditional instruction. However, the study was limited because the researchers did not include details about how they improved feedback in the game design to support students more effectively. Also, the study did not specify or ask the students what held their interest in Math-Island over the two years (Yeh et al., 2019).

***Benefits of DGBL***

In light of what we know about how children learn, how shall we best integrate game-based learning into elementary mathematics to increase conceptual understanding? As presented in Appendix A: Scope of the Research, five of the studies related to DGBL used blended instruction but took different approaches to integrating the games (Bang et al., 2022; Zhang et al., 2020; Engledowl et al., 2021; Yang et al., 2018; Yeh et al., 2019). Four studies allowed students to pace themselves at home or in the classroom (Gresalfi et al., 2017; Hulse et al., 2019; Yeh et al., 2019; Bang et al., 2022). Yeh et al. (2019) allowed students to play in a blended learning environment as well as self-paced in school or assigned Math Island as homework.

Throughout the eight GDBL studies, Zhang et al. (2020) was the only study without significant cognitive improvement on the math concepts posttest. However, Zhang et al. (2020) conducted a transfer test three days after the posttest that revealed the experiment group had a higher learning effect on the magnitude of understanding than the control. Therefore, DGBL had some positive impact on students' conceptual understanding.

Seven of the eight DGBL studies noted that students enjoyed the game and found it motivating. The only study that did not mention motivation was Yang et al. (2018). The reason for this, however, was due to the nature of that study, not the nature of that game. Yang et al. (2018) compared two identical games, and the only difference was the feedback the student received on a failed question. Games were an alternative method to engage students in learning mathematics (Engledowl et al., 2021). In a situation where teachers could have a variety of games available, students who could choose the game they play would be more motivated (Gresalfi et al., 2017). Additionally, while some studies noted that students increased conceptual understanding regardless of feedback and aesthetics, the added gamified features motivated students to collect all of the badges or upgrade their island (Hulse et al., 2019; Gresalfi et al., 2017; Yang et al., 2018). This led to students playing more than was required, giving them an increased conceptual understanding of the process (Kiili et al., 2018; Yeh et al., 2019).

Four studies compared one or more digital games to another and isolated the games or game features to specific groups (Zhang et al., 2020; Yang et al., 2018; Hulse et al., 2019; Gresalfi et al., 2017). While Yang et al. (2018) and Hulse et al. (2019) demonstrated that their study had improved conceptual understanding, they did not describe how the games impacted meeting specific learning objects. Zhang et al. (2020), Kiili et al. (2018), and Bang et al. (2022) filled this gap. If Slice Fractions and Motion Math were played together in Zhang et al.'s study (2020), then all of the experiment objectives would have been met within a single experiment group. Kiili et al. (2018) found that the Semideus School application improved the students' conceptual understanding. However, they only improved upon two of the four tasks the researchers anticipated the students would achieve. My Math Academy, on the other hand, included 130 games that covered 96 concepts and skills (Bang et al., 2022). These results illustrate that games have a limited number of objectives they could meet, and if students played more games within a unit or lesson, they would have a deeper conceptual understanding (Bang et al., 2022).

Bang et al. (2022), Kiili et al. (2018), Yang et al. (2018), Yeh et al. (2019), and Hulse et al. (2019) emphasized the importance of feedback and assessment in games to inform and guide students in improving conceptual understanding. Feedback was an important characteristic of all the digital games because they encouraged students to take risks, make mistakes, and encounter more difficult concepts in a non-threatening environment (Hulse et al., 2019; Bang et al., 2022). The interactivity, feedback, and adaptive challenges provided by games developed motivation and caused improvement in conceptual understanding without students realizing it (Bang et al., 2022; Yeh et al., 2019; Hulse et al., 2019). My Math Academy was created to provide personalized content to students within their zone of proximal development (Bang et al., 2022). The program analyzed students' skills and used embedded assessments to adjust the difficulty of games and presented material for students to practice less developed skills and knowledge. In Yang et al. (2018), the progressive prompting assessment procedure was an effective method of providing feedback and reducing students' misconceptions because it presented the correct expressions and gave students a second chance to learn from their misunderstanding when asked the original question a second time. If students were not given a second chance at the original question or skills missed, they may not have taken careful consideration to retain the feedback provided.

### ***Drawbacks of DGBL***

Feedback could have been given by the teacher after playing the games or given by the software during the games. When the software gave feedback to students, the teachers benefitted from earning more preparation time and grading, but there were many drawbacks as well. Students received feedback through percentages of completed work and rewards like coins and badges (Kiili et al., 2018). When the software delivered feedback, the teachers were not always needed to be a guide or provide scaffolding during the activity (Yang et al., 2018; Hulse et al., 2019; Yeh et al., 2019). Instead, teachers had to adapt to work around the implemented system to examine when and how to administer hints to support students as they solve problems during DGBL (Yang et al., 2018). When teachers were not needed to moderate, guide, or provide feedback, they had fewer opportunities to build relationships with students. Bang et al. (2022) and Kiili et al. (2018) were the only two DGBL studies that used the feedback of students' game achievements as a means to inform teachers to modify their lessons to student's needs and progress levels. Not all games allowed teachers access to students' progress and attempts. If teachers were not integrating DGBL as a reward or free play, this could place teachers at a disadvantage in modifying the curriculum to students' needs and meeting gaps in students' knowledge.

The setting did not play a significant factor in the eight DGBL studies, as outlined in Appendix B. Instead, math centrality played a significant role. All the DGBL studies were math-centric except for Yang et al. (2018). Most of the games in the DGBL studies were created by field experts and mathematicians (Bang et al., 2022; Kiili et al., 2018; Engledowl et al., 2021; Yang et al., 2019; Yeh et al., 2019; Hulse et al., 2019). However, not all of these games were made available to the public. Furthermore, many published games on the App Store were created to support procedural knowledge (rote memorization) rather than conceptual knowledge (Kiili et al., 2018). Procedural knowledge could not be considered a drawback on its own, but the focus of this research study was conceptual knowledge.

DGBL is a supplemental tool to enhance learning. Kiili et al. (2018) had students play Semideus School without additional instruction. Although students gained increased conceptual understanding, their game could not teach the comparison and density tasks. On the other hand, Zhang et al. (2020) had teachers use traditional instruction methods in addition to playing either Slice Fractions or Motion Math. The results denoted that a singular game could not teach every concept or learning objective they were anticipating to meet. This demonstrated that DGBL could be used as a supplemental tool but may require other more traditional or non-game-based teaching methods (Zhang et al., 2020; Engledowl et al., 2021).

**Summary**

In light of what we know about how children learn, how shall we best integrate game-based learning in elementary mathematics to increase students' conceptual understanding? This literature review compared findings from TGBL and DGBL to provide a fuller picture of factors to consider when integrating games in the elementary mathematics classroom. According to the 15 articles, teachers needed to consider the educational context of the lesson, such as the environment, style of education, the number of games played, and what games aligned with the learning objectives. It was also important that the GBL was motivating, enjoyable, modifiable, math-centric, and able to provide feedback. This was vital for the teachers as they fulfilled their role as moderators and guides to support students and build relationships. Chapter Three utilized these key findings to draw insights, potential applications in the field, and implications for future studies.

# Chapter Three: Insights/Applications/Future Studies

After separating the 15 articles by each branch of GBL and analyzing the benefits and drawbacks in Chapter Two, Chapter Three answers the research question: In light of what we know about how children learn, how shall we best integrate game-based learning in elementary mathematics to increase students' conceptual understanding? Chapter Three refers to both Appendices to explicate insights about integrating TGBL and DGBL effectively. Appendix A: Scope of the Research outlines the 15 articles by methodology, a branch of game-based learning, and how each researcher integrates the games into education. Appendix B: Factors that Make Integration of TGBL And DGBL More Effective outlines the same 15 articles within the literature review. The Appendices list the factors that affect integration. Chapter Three analyzes the benefits and drawbacks of those factors by drawing insights from the research. It also provides applications for future use and recommendations for future research.

## Insights Gained from the Research

As the evidence from the articles suggests, students will sometimes gain conceptual understanding from GBL. While Appendix B does not reveal any trends from the 15 articles that directly impact increasing conceptual knowledge, teachers should still be aware of the contributing factors. Factors impacting the integration of GBL in elementary mathematics are environment, style of education, the number of games, student enjoyment modifiability, math centrality, feedback, and the teacher's role. Three categories contain these various factors. The categories are educational context, key characteristics, and the teacher's role.

### *Education Context*

Based on the literature review, the most popular integration method for DGBL and TGBL is blended learning with traditional instruction. However, both branches have different secondary approaches. Intervention (a stand-alone activity) is another appropriate integration method for TGBL (Bustamante et al., 2022; Elofsson et al., 2016; Nasir et al., 2020). For DGBL, the studies suggest students interact with games during free time or as self-paced activities (Bang et al., 2022; Zhang et al., 2020; Engledowl et al., 2021; Yang et al., 2019; Yeh et al., 2019). Games are supplemental tools to enhance education. Teachers can use either branch of GBL as an activity in a lesson, as additional support for students to strengthen their mathematical skills, or as an assessment tool to record a student's progress.

Each instance of GBL has a learning objective that the teacher wants the students to meet. However, both traditional and digital games have limitations in the number of learning objectives they can connect to at a time. While three of the DGBL articles suggest that integrating multiple games into a lesson or unit can maximize the number of learning objectives students meet, there is inadequate evidence from the seven traditional game-based learning articles to suggest a similar trend.

GBL is not intended for a one-size-fits-all approach. Teachers attempting to integrate traditional games into their lessons need to consider the game, space, time, and relation to learning objectives. Specifically, a controlled environment during an intervention will produce a different result than a less controlled environment during a blended lesson. There is inadequate evidence from the eight digital game-based learning articles to suggest a trend in learning outcomes concerning the environment.

### *Key Characteristics*

Fourteen articles from the literature review align the games to specific math objectives or curricula. As two DGBL articles in the literature review suggest, a math-centric game does not automatically increase conceptual understanding. Additionally, not all games are made by mathematicians. Most traditional games are likely not made by mathematicians, but teachers can still integrate the games into the mathematics curriculum. To integrate either branch of GBL, teachers must ensure the games have a correlation to the math objectives, determine how the game will increase students' conceptual understanding, and how teachers will be able to assess whether students gained any knowledge.

Most articles in the literature review agree that games are enjoyable and motivating for learning. The interactive features of the game increase motivation and provide greater conceptual understanding gains to students. Two DGBL studies measure the impact of gamified versus non-gamified design on students' learning (Hulse et al., 2019; Gresalfi et al., 2017). The evidence from both studies suggests that removing gaming aesthetics does not impact students' conceptual understanding but does impact their motivation to play games. These studies propose that learning does not have to be stripped of enjoyable activities to generate a conceptual understanding of mathematical concepts.

According to the evidence in the literature review and Appendix B, the modifiability of traditional games is significant, but not for digital games. With traditional games, the teacher can adapt the game to have more opportunities for assessment, practice with specific skills, or remove features that do not support learning. None of the DGBL studies modify the applications to add mini-games or additional features to teach more objectives. For this reason, those games are classified as not modifiable. Articles from the DGBL studies suggest that students play more than one game within a session or unit to gain better conceptual understanding than their counterparts.

### *The Teacher's Role*

The access teachers have to students' progress impacts the teacher's role positively and negatively. If teachers have access to students' progress, then the teachers can adapt the curriculum to meet students' needs. However, teachers will have limited interactions with students to give feedback and assess learning during the gameplay. They will need to adapt their practice to still interact with students while they are using the software. Therefore, teachers should consider the quality of feedback that games give students when implementing DGBL. This includes both feedback to the student (i.e., Two-Step Progressive Prompting) and feedback to the teacher, such as progress reports. The literature suggests that teachers' roles as moderators in TGBL are an important factor in the effectiveness of integration and increasing conceptual understanding. Teachers build stronger relationships with students, invest more in students' learning, and can modify games in progress to include more questions or mini-games for students to interact with and strengthen conceptual knowledge.

Eight DGBL articles suggest that feedback is an important characteristic. Digital games encourage students to make mistakes and solve complex concepts in a low-risk environment. Yang et al. (2018) demonstrated the importance of effective feedback that guides students to retry problems. Some games do not correct students or force them to learn from their mistakes other than correcting them without further guidance. Teachers must carefully consider the quality of feedback the games provide and how they can adapt to remain active in students' learning.

**Applications**

Based on the illustration in Appendix A, TGBL is best integrated as blended learning, combining two classes, or as an intervention. Teachers can blend TGBL into the classroom as an activity with the lesson. This integration method would be appropriate, but teachers must be cognizant of the time constraint as they split the lesson into two parts. Teachers can combine movement games with P.E. to meet both standards. Another method teachers can integrate TGBL is as an intervention assessment tool or as support for students who need more practice with specific math skills. Every TGBL article from Chapter Two suggests that games are enjoyable for students. When teachers integrate games as added support or assessment of knowledge (not graded), students are placed into a low-risk environment to play and perform. Teachers can integrate TGBL into several classroom settings; however, they must carefully consider the environment where the class will play the game. For instance, if the class plays kickball, they may want to play outside or in the gym. The teacher can choose to play as a free choice activity, blend the game into the mathematics class as an activity, or integrate it into P.E. Teachers should also consider the modifiability of a traditional game. The game design should also be flexible enough to include new rules or objectives that allow students to strengthen their conceptual knowledge of mathematics.

Appendix A suggests that teachers integrate DGBL as blended learning or self-paced activities. What makes DGBL activities interesting is their versatility. The feedback from the software guides students so teachers can integrate the games as additional activities. They can fit in after a lesson, during free choice activity time, as homework, or in stations. Ideally, the teacher should have access to students' profiles to assess the student's progress and adapt instruction to meet the student's academic needs accordingly. If the games do not meet certain skills or objectives, teachers can adapt the lessons and find another game. As the literature review articles indicate, students meet more objectives when they play more games because the games meet a finite number of skills. Teachers can assign these additional games as homework or during station work to give students variety in their activities.

Teachers may find integrating games daunting because they want to make them enjoyable and challenging for students. However, 14 articles allude to the fact that children enjoy playing regardless of the game. Regarding DGBL, students enjoy gamified and non-gamified designs but are more drawn to gamified designs. Teachers should consider what features the games include and if they enhance or distract from teaching mathematics concepts.

What is most important for both branches of GBL is ensuring the game aligns with the math standards and generates conceptual understanding, not procedural knowledge (e.g., rote memorization). For instance, a teacher may want to integrate kickball into instruction. Kickball does not have any connection to specific mathematical standards. The teacher can modify the game rules to focus more on mathematics, such as solving a problem to steal a base, having the outfield answer the incorrect answer, or having students solve to get a player out. These examples would increase the math centrality, but the inclusion of math is twofold. To include conceptual understanding, the outfielders must answer how to correct and solve the problem, not just state an answer.

**Recommendations for Future Studies**

There are multiple recommendations for studying game-based learning. One recommendation is specifically for traditional games, and the rest apply to both teaching strategies. The recommendations for all GBL are based on the trends in limitations throughout the literature review. The limitations include small sample sizes, short experiment time, and no comparison of DGBL and TGBL versions of games to determine students' preferences.

The first recommendation is needed for more studies that align classic traditional games (e.g., bingo, Uno, I-spy, dodgeball, tag, etc.) to curriculum or common core standards and play them to determine what learning objectives are met. In these studies, the researchers should adapt the game or indicate what objectives are not met and what causes the game to miss the objectives, as Bustamante et al. (2022), Zhang et al. (2020), and Kiili et al. (2018) demonstrate.

The second recommendation is to include a larger sample size of students in studies. Larger sample populations of students will enhance the credibility of the research beyond validating GBL's effectiveness in a region or school. Researchers can also include multiple age levels to determine if the game of choice is viable for use in numerous grades.

The third recommendation for future research is to lengthen the time of the studies. Four studies have students interact with the game of choice for no more than 90 minutes (Gresalfi et al., 2017; Engledowl et al., 2021; Yang et al., 2018; Hulse et al., 2019). This time restriction does not adequately reveal to researchers the long-term impact GBL has on students' conceptual understanding and motivation. Researchers can investigate the minimum threshold of gaining a conceptual understanding of mathematical concepts, how long students must play to meet learning objectives, and how to keep students engaged from long-term, repetitive gameplay.

A fourth recommendation is to compare DGBL to TGBL versions of games (e.g., golf, baseball, solitaire) to see the impact the games have on learning and if students have a preference over one branch of GBL. The final and most necessary recommendation for the field of study is to include more qualitative studies. There is only one qualitative study in Appendix A, which is insufficient to conduce definitive results.

**Conclusion**

Students understand games. They prefer interactive lessons with collaborative and challenging activities over traditional instruction (Nasir et al., 2020). Lessons do not need to be stripped of enjoyable activities to build conceptual knowledge. In light of what we know about how children learn, how shall we best integrate game-based learning in elementary mathematics to increase students’ conceptual understanding? This research study identifies integration methods of digital and traditional games as well as factors that impact the effectiveness of GBL and gains in conceptual knowledge. Overall, game-based learning is a viable supplemental tool that enhances elementary mathematics instruction and increases students' conceptual knowledge.

> Game-based learning environments have a structure that supports development of students’ skills and carries information patterns that are unique to the field it is prepared for, and in addition to characteristics of providing students with opportunities to have a good time, they also have instructive and reinforcing characteristics in the activity that takes place in the game (Çelik, 2019, p. 452).

**References**

Adkins, S. (2021). *2021-2026 US game-based learning market – metaari report " serious play conference*. Serious Play Conference. https://www.seriousplayconf.com/downloads/2021-2026-us-game-based-learning-market-metaari-report/

Avdiu, E. (2020). Integration of Game-Based Learning as a Teaching Method in Elementary Education. Üniversitepark Bülten, 9(1), 50–. https://doi.org/10.22521/unibulletin.2020.91.5

Bang, H. J., Li, L., & Flynn, K. (2022). Efficacy of an Adaptive Game-Based Math Learning App to Support Personalized Learning and Improve Early Elementary School Students' Learning. Early Childhood Education Journal, 51(4), 717–732. https://doi.org/10.1007/s10643-022-01332-3

Bouchrika, I. (2023, June 27). *39 interactive learning statistics: 2023 data, Trends & Predictions*. Research.com. https://research.com/education/interactive-learning-statistics#:~:text=74%25%20of%20teachers%20have%20digital,games%20(Murray%2C%202012).

Bustamante, A. S., Begolli, K. N., Alvarez-Vargas, D., Bailey, D. H., & Richland, L. E. (2022). Fraction ball: Playful and physically active fraction and decimal learning. Journal of Educational Psychology, 114(6), 1307–1320. https://doi.org/10.1037/edu0000714

Çelik, H. C. (2019). The effect of modelling, collaborative and game-based learning on the geometry success of third-grade students. Education and Information Technologies, 25(1), 449–469. https://doi.org/10.1007/s10639-019-09983-3

Chen, Y., & Zhao, S. (2022). Understanding Chinese EFL Learners' Acceptance of Gamified Vocabulary Learning Apps: An Integration of Self-Determination Theory and Technology Acceptance Model. *Sustainability, 14*(18), 11288. https://doi.org/10.3390/su141811288

Elofsson, J., Gustafson, S., Samuelsson, J., & Träff, U. (2016). Playing number board games supports 5-year-old children's early mathematical development. The Journal of Mathematical Behavior, 43, 134–147. https://doi.org/10.1016/j.jmathb.2016.07.003

Engledowl, C., Al-younes, M., Chamberlin, B., & Stanford, T. (2021). Learning acquired from a computer game-based early algebra intervention. School Science and Mathematics, 121(8), 495–508. https://doi.org/10.1111/ssm.12500

Entertainment Software Association. (2022, June 10). *2022 essential facts about the video game industry*. Entertainment Software Association. https://www.theesa.com/resource/2022-essential-facts-about-the-video-game-industry/

Gresalfi, M. S., Rittle-Johnson, B., Loehr, A., & Nichols, I. (2017). Design matters: Explorations of content and design in fraction games. *Educational Technology Research and Development*, *66*(3), 579–596. https://doi.org/10.1007/s11423-017-9557-7

Halper, D. L. (2021, September 15). *Can radio really educate?*. JSTOR DAILY. https://daily.jstor.org/can-radio-really-educate/

Hulse, T., Daigle, M., Manzo, D., Braith, L., Harrison, A., & Ottmar, E. (2019). From here to there! Elementary: a game-based approach to developing number sense and early algebraic understanding. Educational Technology Research and Development, 67(2), 423–441. https://doi.org/10.1007/s11423-019-09653-8

Kiili, K., Moeller, K., & Ninaus, M. (2018). Evaluating the effectiveness of a game-based rational number training - In-game metrics as learning indicators. Computers and Education, 120, 13–28. https://doi.org/10.1016/j.compedu.2018.01.012

Math Snacks Team. (2023). *Math Snacks: Teaching with*. MathSnacks.org. https://mathsnacks.org/teaching-with.html

Matic, L. J., Karavakou, M., & Grizioti, M. (2023). Is Digital Game-Based Learning Possible in Mathematics Classrooms?: A Study of Teachers' Beliefs. *International journal of game-based learning*, *13*(1), 1–18. https://doi.org/10.4018/IJGBL.323445

Minas, M. (2020, March 31). *Get out of my House*. YouTube.

https://www.youtube.com/watch?v=QQdiRTHWhwI

Minas, M. (2023, February 6). *Choc chip cookies*. YouTube. https://www.youtube.com/watch?v=V6_HLN2OFLU

Molina, Concepción. (2014). *Sedlinsights - Sedl Archive*. SEDL Insights. Retrieved November 3, 2022, from https://sedl.org/insights/1-4/teaching_mathematics_conceptually.pdf

Nahdi, D. S., & Jatisunda, M. G. (2020). Conceptual Understanding And Procedural Knowledge: A Case Study on Learning Mathematics of Fractional Material in Elementary School. Journal of Physics. Conference Series, 1477(4), 42037–. https://doi.org/10.1088/1742-6596/1477/4/042037

Nasir, A., Svazwani, N., Rasid, M., & Singh, P. (2020). Learning mathematics through card game: enhancing children's numeracy skills. *Science International*, *32*(4), 465–469. ISSN 1013-5316

Noffisinger, D. (2019, September 30). *How Digital Game-Based Learning Improves Student Success*. Prodigy Education. https://www.prodigygame.com/main-en/blog/digital-game-based-learning/

Piaget, J. (1962). *Play, dreams, and imitation in childhood*. W. W. Norton & Company.

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist*, *50*(4), 258–283. https://doi.org/10.1080/00461520.2015.1122533

Russo, J., Bragg, L., Russo, T., & Minas, M. (2023). Identifying the Characteristics of Non-Digital Mathematical Games Most Valued by Educators. Education Sciences, 13(1), 30–. https://doi.org/10.3390/educsci13010030

Syahrial, A., Maison, Kurniawan, D. A., & Perdana, R. (2020). A study of Traditional Games "Engklek" in Mathematics for Elementary School. Journal Ilmu Pendidikan (Jakarta), 26(1), 15–. https://doi.org/10.17977/um048v26i1p15-21

Takeuchi, L., & Vaala, S. (2014). *Level up learning: A national survey on teaching with Digital*

*Games*. Joan Ganz Cooney Center. https://www.joanganzcooneycenter.org/wp-content/uploads/2014/10/jgcc_leveluplearning_final.pdf

Vygotsky, L. (1978). *Mind in Society: Development of Higher Psychological Processes*. Harvard University Press.

Yang, K.-H., Chu, H.-C., & Chiang, L.-Y. (2018). Effects of a Progressive Prompting-based Educational Game on Second Graders’ Mathematics Learning Performance and Behavioral Patterns. Educational Technology & Society, 21(2), 322–334. ISSN 1436-4522

Yeh, C. Y. C., Cheng, H. N. H., Chen, Z.-H., Liao, C. C. Y., & Chan, T.-W. (2019). Enhancing achievement and interest in mathematics learning through Math-Island. Research and Practice in Technology Enhanced Learning, 14(1), 1–19. https://doi.org/10.1186/s41039-019-0100-9

Zhang, L., Shang, J., Pelton, T., & Pelton, L. F. (2020). Supporting primary students’ learning of fraction conceptual knowledge through digital games. Journal of Computer Assisted Learning, 36(4), 540–548. https://doi.org/10.1111/jcal.12422

**Appendix A: Scope of the Research**

| Selected Author(s) name & year of pub. in Chapter Two | Qual. Quant. Mixed Method | TGBL | DGBL | Blended | Home work | Intervention | Self-paced /free time | Station | Two or more classes combine | Interview No integration observed |
|---|---|---|---|---|---|---|---|---|---|---|
| **Çelik (2019)** | Mixed Method | X | | X | | | | | | |
| **Bustamante et al. (2022)** | Quant. | X | | X | | X | X | | X | |
| **Elofsson et al. (2016)** | Quant. | X | | | | X | | | | |
| **Russo et al. (2023)** | Mixed Method | X | | | | | | | | X |
| **Avdiu (2020)** | Qual. | X | | | | | X | | X | X |
| **Syahrial et al. (2020)** | Mixed Method | X | | | | | | | | X |
| **Nasir et al. (2020)** | Mixed Method | X | | | | X | | | | |
| **Bang et al. (2022)** | Mixed Method | | X | X | | X | X | X | | |
| **Zhang et al. (2020)** | Quant. | | X | X | | | | | | |
| **Kiili et al. (2018)** | Quant. | | X | | | X | | | | |
| **Engledowl et al. (2021)** | Quant. | | X | X | | | | | | |

| Selected Author(s) name & year of pub. in Chapter Two | Qual. Quant. Mixed Method | TGBL | DGBL | Blended | Home work | Intervention | Self-paced /free time | Station | Two or more classes combine | Interview No integration observed |
|---|---|---|---|---|---|---|---|---|---|---|
| **Yang et al. (2018)** | Quant. | | X | X | | | | | | |
| **Hulse et al. (2019)** | Quant. | | X | | | X | X | | | |
| **Yeh et al. (2019)** | Mixed Method | | X | X | X | | X | | | |
| **Gresalfi et al. (2017)** | Mixed Method | | X | | | | X | | | |

**Appendix B: Factors that Make Integration of TGBL and DGBL More Effective**

| | Educational Context | | | | | Key Characteristics | | | Teacher's Role | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Selected Author(s) name & year of pub. in Chapter Two** | **TGBL** | **DGBL** | **# of games in study** | **↑ con. und.** | **Found setting important** | **Math centric/ aligned with learning obj.** | **Enjoyable & motivating** | **Game was suggested as modifiable** | **Software gave feedback to students** | **Guided students & adapted lessons** |
| **Çelik (2019)** | X | | 6 | | X | X | X | X | | |
| **Bustamante et al. (2022)** | X | | 1 | X | X | X | **X** | X | | X |
| **Elofsson et al. (2016)** | X | | 5 | X | X | X | X | | | |
| **Russo et al. (2023)** | X | | 53 | | | X | X | X | | |
| **Avdiu (2020)** | X | | 4 math<br><br>10+ not math related | | | X | X | X | | X |
| **Syahrial et al. (2020)** | X | | 1 | | | X | X | X | | |
| **Nasir et al. (2020)** | X | | 1 | X | | X | X | | | X |
| **Bang et al. (2022)** | | X | 130+ | X | X | X | X | X | X | X |
| **Zhang et al. (2020)** | | X | 2 | | | X | X | | X | |

| | **Educational Context** | | | | | **Key Characteristics** | | | **Teacher's Role** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Kiili et al. (2018)** | | X | 1 | X | | X | X | | X | X |
| **Engledowl et al. (2021)** | | X | 3 | X | | X | X | | X | |
| **Yang et al. (2018)** | | X | 1 | X | | | | | X | |
| **Hulse et al. (2019)** | | X | 1 | X | | X | X | | X | |
| **Yeh et al. (2019)** | | X | 1 | X | | X | X | | X | X |
| **Gresalfi et al. (2017)** | | X | 5 | X | | X | X | | X | |