Exploring Game Design and Use in an Elementary Mathematics Classroom

by

Busra Sahin Celik

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Abstract

In recent years, game-based learning has gained significant attention for its potential to make learning more engaging and less intimidating (Clark et al., 2016). The integration of games with educational content can make learning more interactive, enjoyable, and less stressful (Huang et al., 2013). However, not all educational games are of equal value (Russo et al., 2018) and the way they are designed may influence students' attitudes toward mathematics. This qualitative study examines the use of two games with different design qualities in a Grade 4 classroom. Specifically, it investigates students' reported experiences with each game and their teacher's perspective regarding the design quality and use of mathematics games in her classroom. I gathered data through classroom observations, student questionnaires, teacher initial and follow-up interviews, and video recordings of small-group gameplay sessions. I conducted a thematic analysis to identify recurring patterns and meaningful insights into the design and use of these mathematics games in this classroom. The findings provide insights into the need to find a balance between competition and collaboration; luck and skill; and familiarity and novelty as features of game design that may support student engagement and foster positive attitudes towards mathematics learning. This study also shed lights on three aspects of the use of mathematics games that teachers should consider as they design or select games for use in their mathematics classrooms: intended purpose(s), group composition, and adaptability. The study also offers practical insights for teachers who are designing or using games in their mathematics classroom.

Chapter 1: Overview, Purpose & Research Questions

Mathematics, a cornerstone of our education system, is not just a subject that enables logical reasoning and problem-solving; it is a tool that aids in understanding the world around us (Kiili et al, 2018). Despite its significance, many students have negative attitudes toward mathematics and feel that they are “not math people” (Rieche, 2019, p. 33). Attitudes toward mathematics are an affective variable that has been extensively studied in relation to mathematics learning and achievement (Chaman & Callingham, 2013). Although definitions of attitude in mathematics education research vary, many include both cognitive and affective elements (Aquilina et al., 2024). As educational systems continue to emphasize the importance of science, technology, engineering, and mathematics (STEM) education, it is important to address negative attitudes toward learning and doing mathematics to ensure students are not deterred from these critical fields (Kiili et al., 2018).

One approach that has gained significant attention in recent years for its potential to make learning more engaging and less intimidating is “game-based learning” (Clark et al., 2016). The integration of educational content within a game format can transform the learning experience, making it more interactive, enjoyable, and, in some cases, less stressful (Huang et al., 2013). However, not all educational games are of equal value (Russo et al., 2018). The design, objectives, and underlying pedagogical approaches included in games can vary widely, potentially leading to different outcomes in terms of both learning and impact on students’ attitudes toward mathematics. Researchers have identified many qualities of effective educational games in various subject areas (Dondio et al., 2023). For instance, the importance of aligning game design with specific learning objectives, fostering deep engagement in targeted skills, and ensuring that games go beyond mere entertainment to provide opportunities for exploration and discovery has been underscored in order for mathematics games to be educationally rich (Buchheister et al., 2017; Jackson et al., 2013; Swan, 2004). I discuss several qualities of games in greater detail in Chapter 2.

In my view, as educational games become increasingly integrated into pedagogical approaches, it is important to understand how their design quality and use might influence students' attitudes toward mathematics. Although there are some studies that explore the general effects of educational games on mathematics attitudes (Dondio et al., 2023), I was unable to locate any studies on this topic conducted with students in the context of Canadian curricula. In this study, I examined two different game designs to learn more about how Grade 4 students experience each game and gain insights into the design features which might help to ensure a more positive learning experience for students. I have chosen to focus on one mathematics concept for this study, the part-whole aspect of learning fractions. This concept has been shown to be an area that many students find challenging (Charalambous & Pitta-Pantazi, 2006) and where some experience mathematics anxiety (Bonsel, 2022) or have negative attitudes. It is also a mathematics concept which many teachers struggle to teach (Charalambous & Pitta-Pantazi, 2006).

Before describing the purpose of this study and explaining my research questions, I discuss my motivation for conducting this research and my positionality in relation to this study.

Motivation and Positionality

Although mastering mathematical concepts is crucial for students' academic and future professional success (Kiili et al., 2018), I have seen mathematics become a source of stress and negative attitudes for many students. From the crowded classrooms of Türkiye to the diverse educational settings of Canada, I have observed this trend firsthand. Many students, regardless of their background, struggle with the pressure and fear associated with mathematics problems, tests, and even everyday classroom activities. I have also noticed that students often enter the mathematics classroom with preconceived notions about the subject. Some consider it too challenging or believe that they simply “aren't [a] math person” (Rieche, 2019, p. 33). Such beliefs, often stemming from early negative experiences or societal stereotypes, can heavily influence a student’s attitudes toward mathematics, even before a lesson begins (Haciomeroglu, 2017). These observations led me to think about how educators might transform the mathematics learning experience from a source of stress to one of enjoyment and an opportunity for building confidence.

Game-based learning (GBL) has emerged as a potential answer, particularly in the era of digital technology (Huang et al., 2014). Games are intended to be engaging and interactive (Huang et al., 2014). When designed well, they can turn challenging concepts into enjoyable puzzles, helping students to learn without anxiety and improving their attitudes toward mathematics learning. During the COVID-19 pandemic, the shift to remote learning presented unique challenges in Türkiye but also provided me with an opportunity to consider the value of game-based approaches. Like many Turkish educators, I embraced digital games to maintain student engagement in online mathematics classrooms during lockdowns. However, with so many educational games out there, I thought it was important to figure out which ones might help to change students’ attitudes towards mathematics. I was also interested in understanding how in-person, paper-based games might be used to improve students’ attitudes and enhance their mathematics learning. My interest in focusing on in-person, paper-based games was based on my understanding that they provide a hands-on multisensory experience that encourages direct interaction, face-to-face communication, collaboration, and teamwork.

Given these experiences, the general objective of this study was to explore features of game design and use in a Grade 4 classroom and how they might impact students' attitudes towards mathematics from the perspectives of the classroom teacher and the students. Through this exploration, I have gathered insights that educators can draw on when creating or using games to promote positive and less stressful learning.

I completed my B.Sc. degree four years ago in Türkiye and have taught mathematics to grades 4-8 students in Ankara. Since then, I have also taught students from the United States (US) in online settings, engaged in in-person tutoring of children in Winnipeg, Manitoba, and been an educational assistant in schools in Winnipeg. During my B.Sc. degree, I studied my final year courses from home because of the pandemic. As a pre-service teacher at an elementary school, I engaged in online mathematics instruction because the school system was limited to remote learning. I observed that many students turned off their cameras and microphones and were reluctant to participate in virtual classroom activities. This reluctance seemed to stem from negative attitudes toward mathematics and possibly to mathematics anxiety for some students. To try to overcome this, I implemented game-based learning strategies, leveraging familiar games such as bingo, puzzles, and competitions. I noticed positive responses and observable changes in student engagement when I used these activities.

My positionality in relation to this study is rooted in these experiences. While implementing a bingo-like game called "Tombamath" in the online class I was teaching, I observed a shift in students' attitudes toward the subject. In this study, I explore the potential for two games that I designed, Tombamath and the "Fraction Story Game", to help students have more positive attitudes toward mathematics learning, specifically learning about the part-whole aspect of fractions. An overview of both games is included in Appendix A. I acknowledge that my positive experiences with Tombamath shaped my expectations for this study. That is, I anticipated that playing Tombamath would positively influence students' attitudes toward learning mathematics, specifically the part-whole aspect of fractions. I had not used the Fraction Story Game with students prior to this study and did not have expectations for how the features of this game might impact students. While my personal experiences serve as a foundation for this research, I recognize the importance of maintaining transparency and reflexivity, of considering alternative perspectives and recognizing limitations in order to contribute credible and nuanced insights to the field of mathematics education.

Purpose of the Study and Research Questions

In this study, I investigated game-based learning as a pedagogical tool for promoting a positive and less stressful learning environment among Grade 4 students in a classroom in Manitoba, Canada. Three research questions guide this study:

1. What are the Grade 4 students' reported experiences as they engage in game-based learning focused on fractions in relation to the design characterises of two games?
2. What is the teacher's perspective regarding: (a) the design quality and (b) use of games for teaching and learning mathematics with Grade 4 students?
3. What are the researchers' observations of the design characteristics of each game given the data that was gathered in the study? What improvements might be made to each game?

Overview of Thesis

In Chapter 2, I briefly discuss three theoretical frameworks which I drew on for this study. I also review recent literature concerning mathematics attitudes, game-based learning, and the intersection of these areas. In Chapter 3, I describe the methodology and research methods employed. In Chapter 4, I present the observations and findings of the research. In Chapter 5, I discuss the findings in relation to the research questions and the literature, identify some limitations and make some recommendations based on the study.

Chapter 2: Theoretical Perspectives and Review of Relevant Literature

In this chapter, I explain the theoretical perspectives that guided my study. This is followed by a review of some recent literature in the areas of mathematics attitudes, game-based learning, and the intersection of these areas. I also discuss some of the current literature related to teaching and learning fractions with a focus on representations of part-whole, as this is the mathematics concept which is explored in the two games that I designed and used in this study. The findings from the studies I reviewed as well as the methodologies of these studies informed the design of my study.

Theoretical Perspectives

I drew on three theoretical frameworks as I investigated the relationship between the design features of the two games and mathematics attitudes: constructivism (Piaget, 1980; Vygotsky, 1962), self-efficacy theory (Bandura, 1977), and game-based learning theory (Zhong, 2019). In this section, I describe a few elements of each theory and explain the connections I saw between the theory and my study.

Constructivism: A Theory of Learning

Constructivism, rooted in the works of Piaget (1980) and Vygotsky (1962), states that teachers cannot simply transmit knowledge to students; students actively construct their knowledge through interactions with their environment (Piaget, 1980; Vygotsky, 1962). Constructivist theories emphasize that learners form new knowledge and experiences based on existing knowledge instead of absorbing information word-by-word from their teachers. In other words, learners use their previous knowledge to build on as they learn new things (Kieu Oanh & Hong Nhung, 2022). Piaget, a central figure in constructivist theory, introduced a model of cognitive development suggesting that learners undergo sequential stages of understanding

(Bada, 2015; Piaget, 1980). Central to Piaget's view is the concept of active learning (Bada, 2015; Piaget, 1980). Learning is an active process in which learners need to engage by asking questions, exploring, and discovering. The constructivist view of learning encourages students to create more knowledge and then reflect on and discuss how their understanding is evolving (Bada,2015).

According to Vygotsky (1962), learning is a collaborative activity where children first engage with their environment on a social level before internalizing these experiences (Ozer, 2004). Over time, these experiences help children form new ideas, drawing upon both their existing knowledge and new encounters (Ozer, 2004). Vygotsky (1978) introduced the notion of the "Zone of Proximal Development" (ZPD). This refers to the gap between what children can achieve independently and what they can understand with the guidance of an adult or more knowledgeable peer. The ZPD underscores the idea that while there may be limits to what a child can grasp at a given age, these boundaries can be extended through social interaction.

Ozer (2004) emphasized that in a constructivist classroom, students actively build knowledge through diverse experiences. This learning environment integrates a wide array of activities that can support the development of reading comprehension and other forms of learning. According to Ozer, collaboration lies at the heart of this approach and peer interactions, ranging from networked projects to collective problem-solving, are encouraged, fostering an environment of feedback and mutual growth. Central to this approach is the incorporation of cognitive strategies that prompt deeper understanding and critical thinking. I think that engaging in carefully designed mathematics games could be one of these diverse experiences. I believe that constructivist theory is an appropriate framework for my study since the goal is for students to be actively engaged in the games, to provide opportunities for students to discuss how their understanding is evolving and for students to work collaboratively with others. In addition, some scholars of game-based learning (GBL) theory, as I discuss below, situate GBL as rooted in constructivism.

Self-efficacy Theory

Self-efficacy theory, as proposed by Bandura (1977), refers to an individual's belief in their capacity to execute specific tasks and achieve particular goals. It is not merely a measure of an individual's skills or capabilities but a reflection of their perception of what they can achieve with those skills (Ahmed & Jabeen, 2011). People with negative emotions tend to have lower self-efficacy, while those who experience positive emotions such as enjoyment tend to have higher self-efficacy (Chen & Tu, 2021). Ahmed and Jabeen (2011) indicate that self-efficacy plays a profound role in shaping students' learning behaviours and outcomes in educational surroundings. Students with high self-efficacy in a specific subject or task tend to approach it with confidence, invest more effort, persist through challenges, and achieve higher levels of mastery (Ahmed & Jabeen, 2011).

As I see it, Bandura's self-efficacy theory aligns well with my research since positive and negative emotions are part of the concept of attitude toward mathematics. Game-based learning (GBL) has the potential to enhance students' intrinsic motivation, as it often incorporates fun, challenge, and engagement (Ryan & Deci, 2000). When learning is enjoyable and stimulating, students are more likely to engage willingly in mathematical tasks, which can lead to decreased mathematics anxiety and improved mathematics attitudes (Su, 2016). GBL, which involves problem-solving, play, and can include collaborative work and competition, is at the core of my research. Studying the implementation of games as an educational tool can provide insights into their impact on students' attitudes.

Game-Based Learning Theory

Game-based learning (GBL) encompasses multiple dimensions that can influence students' learning experiences (Zhong, 2019). In this brief discussion of GBL, I focus primarily on the dimensions of real-time feedback, collaborative learning, creating real-life scenarios, and reflective and evaluative components of GBL. Zhong (2019) indicated that GBL theory is derived from Piaget's cognitive development theory (Piaget, 1974) and that games function as effective learning environments by offering collaborative learning, feedback, real-life scenarios, reflection, and evaluation. These elements collectively contribute to a rich and interactive learning environment that can significantly impact learners' engagement, understanding, and overall educational outcomes (Zhong, 2019). GBL theory is well-suited to my study because both of the games I developed are equipped with real-time feedback mechanisms that inform players about their actions and decisions. This feedback can provide students with immediate insights into their mathematical problem-solving processes. Feedback can help to reduce stress as students receive guidance throughout their learning journey (Huang et al., 2014).

Moreover, the collaborative nature of some games, where students work together to overcome mathematical challenges, can enhance their problem-solving skills and provide mutual support (Zhong, 2019). In both of the games I designed for this study, students work in groups, which may foster collective responsibility and resource sharing. This collaborative approach not only enhances students' mathematical proficiency but can also nurture teamwork and communication skills (Zhong, 2019). In addition, the competitive elements within a collaborative approach can enhance motivation and engagement of the students (Fish et al., 2023). Kiili (2005) indicated that when students compete against each other, they tend to show higher participation. As I explain in Chapter 3, the Fraction Story Game emphasizes collaboration and communication among all groups, while in Tombamath, the collaboration is within each team and teams compete with one another. Competition is an aspect of game design which I explore in further depth in relation to my findings in Chapters 4 and 5.

In addition to feedback and collaborative learning, GBL theory emphasizes the importance of creating real-life scenarios within the game environment (Zhong, 2019). Zhong (2019) indicates that real-life scenarios can reflect mathematics problems that students may encounter in daily life. I would say that by integrating these scenarios into games, students could see the direct applicability of mathematics concepts. One of my games, the Fraction Story Game, emphasizes real-life scenarios while Tombamath does not. According to Zhong (2019), real-life scenarios can help students to connect abstract mathematics concepts to real-life situations.

The reflective and evaluative components of GBL are also evident in my game designs. The design of both games includes that, in each gaming session, students would be encouraged to reflect on their performance and solution strategies. Zhong maintains that this self-reflection allows students to recognize their strengths and areas for improvement, promoting self-awareness and allowing students to take ownership of their learning which can positively influence their mathematics attitudes. Hence, my study includes many aspects of GBL theory at least in the way that I designed the two games. The observations from the study provide insights about how those aspects were experienced by the students and viewed by their teacher. I explore GBL in relation to mathematics learning later in this chapter and return to several aspects of GBL in my analysis of the data.

Review of Relevant Literature

In this section, I review some recent literature in the areas of mathematics attitudes, game-based learning, and the intersection of these areas. I also discuss some literature related to teaching and learning fractions with a focus on representations of part-whole which is a key mathematics concept in the games that I designed. In addition, I connect these games to Manitoba's mathematics curriculum (Manitoba Education, 2013).

Mathematics Attitudes

Mathematics attitudes, as variously defined by researchers (e.g., Haciomeroglu, 2017; Haladyna et al., 1983; Hannula, 2002), encompass learned predispositions and emotional responses to learning and doing mathematics. Neale (1969) emphasized the value of perceptions of mathematics in shaping these attitudes. Mathematics attitudes reflect feelings toward mathematics, including its value, enjoyment, self-confidence, and motivation (Tapia & Marsh, 2005). Moreover, Aquilina et al. (2024) highlighted that attitude towards mathematics is a factor affecting students' achievement. Positive attitudes not only enhance students' willingness to engage but are also correlated with improved mathematical achievement (Antonnen, 1969; Samuelsson & Granstrom, 2007). Conversely, negative attitudes can pose significant challenges to students as they are learning mathematics. The perception of mathematics as a tough subject contributes to problems such as a lack of interest and hindered cognitive activities (Ajisuksmo & Saputri, 2017). Students with negative attitudes may struggle to pay attention to mathematical concepts. Research consistently demonstrates that a considerable number of students in various educational jurisdictions around the world hold poor attitudes toward mathematics (Goodykoontz, 2008).

Recognizing the impact of attitudes on learning outcomes, research underscores the importance of shifting attitudes for an improved learning environment (Haciomeroglu, 2017). Shifting attitudes positively can not only contribute to students' success in mathematics, it can also foster a more conducive atmosphere for learning, as suggested by various studies

(Ajisuksmo & Saputri, 2017; Tapia & Marsh, 2004). In my view, this research aligns with key elements of Bandura's self-efficacy theory (Bandura, 1977) as well. Based on this research, I think that efforts to foster positive attitudes toward mathematics including through GBL could play a vital role in enhancing student's self-efficacy and result in a more effective learning experience.

In keeping with this research, the Manitoba curriculum standards for K-8 mathematics (Manitoba Education, 2013) includes a discussion of attitudes and states that fostering positive attitudes in learning mathematics is essential. The Manitoba curriculum standards also indicates that students with positive attitudes are more likely to be motivated as expressed in the following quotation: "Students with positive attitudes toward learning mathematics are likely to be motivated and prepared to learn, participate willingly in classroom activities, persist in challenging situations, and engage in reflective practices" (Manitoba Education, 2013, p.4). The curriculum standards also emphasize that teachers play a pivotal role in cultivating positive attitudes among students.

Game-Based Learning in Mathematics Education

Game-based learning (GBL) is defined as an active learning technique that uses games to improve students' learning (Tamosevicius, 2022). GBL employs games to promote students' learning where the act of playing teaches critical thinking and problem-solving (Tamosevicius, 2022). In this section, I focus on the application of GBL in mathematics education, exploring some potential benefits and design qualities.

Buchheister et al. (2017) underscore the inherent potential of games in mathematics education. They point out that games, when integrated correctly, move beyond mere distractions or incentives; they evolve into influential pedagogical tools. For games to be effective in the classroom, their design should align closely with targeted mathematical objectives and prompt students to engage deeply in mathematical reasoning (Buchheister et al., 2017). By ensuring that games are tailored to specific mathematical goals, students are prompted to delve deeper into mathematical understanding and critical thinking. Additionally, for a game to be beneficial in a mathematical context, it must be deeply rooted in mathematics (Swan, 2004). This implies that the game should extend beyond entertainment, presenting genuine opportunities for mathematical exploration and discovery.

A notable strength of GBL is its ability to captivate student attention (Buchheister et al., 2017). Engaging, self-directed mathematical games, as emphasized by Jackson et al. (2013), can result in students showing a higher propensity to persist in challenging tasks and display advanced mathematical reasoning. For instance, Betts (2015) used a board game to help students understand fundamental counting principles. Games can also act as springboards for discussion, thereby helping to deepen understanding. These discussions can reinforce mathematical principles and enhance communication skills, both of which are key to deeper mathematics learning (Munter et al., 2015). Documents such as the Manitoba curriculum standards (2013) and the Common Core State Standards for Mathematics (2010) echo this perspective. They emphasize the importance of reasoning and problem-solving in mathematics education, suggesting that genuine dialogue and tasks are pivotal.

Russo et al. (2018) define five principles for educationally rich mathematical game design. First, mathematics games should encourage meaningful mathematical discussion. They suggest that providing students with opportunities to express their thinking and interact with friends will increase their enjoyment and engagement with mathematics. Second, a balance between skill and luck in the game is key in order to maintain students' interest and engagement in the game. According to Russo et al. (2018), when the game is based solely on skill or solely on luck, it can be discouraging for students. Therefore, there should be enough skill to challenge students and enough luck to give everyone a chance to win. Third, they stated that, “exploring and practicing mathematical concepts and skills is central to game strategy and gameplay” (p. 32). Mathematical games can be used to introduce new information and concepts as well as to practice and reinforce existing knowledge. Fourth, mathematics games should include a flexible and adaptable design in order to meet the diverse needs of learners. Well-designed games should have multiple entry points that can be modified as needed to provide critical thinking opportunities for every student (Buchheister et al., 2017). Fifth, educationally rich mathematical games provide opportunities to reinforce home-school connections, allowing adult carers and children to examine mathematics concepts together in an enjoyable way. In addition to these five principals, Gareu et al. (2009) suggest that it is important to consider students familiarity with the games. When games are designed based on structures that students are already familiar with, their confidence and motivation to play tend to increase. I return to a discussion of these game design principles in relation to the observations in this study in Chapter 5.

Impact of Game-based Learning on Mathematics Attitudes. Although I was able to locate several studies that examine the impact of GBL on students’ attitudes toward mathematics, I could not find any studies of the influence of game design on mathematics attitudes that focused on learning fractions. Accordingly, I discuss several studies which investigate the impacts of game-based learning on elementary students, including collaboration, competition, and non-digital games, on attitudes toward any aspect of mathematics.

In their study, Ke and Grabowski (2006) explored the comparative efficacy of cooperative versus individual game-playing in the context of mathematics education. They conducted their study with 125 Grade 5 students from six public school classrooms in Pennsylvania. They used a series of computer games for this study which included mathematics concepts such as measurement, comparing whole numbers, solving simple equations and mapping x and y coordinates. Their findings revealed that students who engaged in cooperative gameplay not only exhibited superior performance in math-related tasks, but they also developed more favourable attitudes towards mathematics than those who engaged in individual game play. They posited that collaboration played a crucial role by facilitating peer interaction and fostering a sense of camaraderie, which can effectively mitigate the feelings of isolation and anxiety that some students experience in mathematics classrooms. While individual gameplay showed benefits in terms of enhancing students' confidence or self-efficacy in their mathematics abilities, cooperative gameplay appeared to be more potent in creating a positive learning environment. This aligns with Lavasani and Khandan's (2011) assertion that collaboration among peers can be instrumental in reducing mathematics anxiety.

Fish et al. (2023) investigated how 1st and 2nd grade children (ages 5–8) learn a challenging mathematics concept -proportion- through different social contexts: competitive, collaborative, or solo play. The sample consisted of 274 children. The results revealed that both competitive and collaborative contexts increased students' motivation, perseverance, and enjoyment compared to solo play. The findings suggested that collaboration led to greater improvements in conceptual understanding, while the competitive setting led to gender differences in attention to proportional reasoning in the presence of competitive cues, with older boys performing poorly in the competition condition. Although my study does not focus on gender difference, this study provides valuable insights into the complexities of competition and collaboration as features of gameplay in the elementary grades.

Kiili et al. (2018) explored the relationships between students' emotions, flow experience, intrinsic motivation, and their performance in a competitive mathematics game. Kiili et al. use the term "flow" to refer to a special form of enjoyment. They conducted their study with 251 Finnish students in Grades 3 and 6. Students played a digital rational number game designed to encourage participation through intra-classroom collaboration and inter-class competition. During three weeks of gameplay, students were free to play the digital rational number game which included number line estimation tasks. After the inter-class competition, the researchers conducted an online questionnaire to gain an understanding of students' experiences. The results showed that students who were intrinsically motivated experienced more positive feelings and higher flow, as well as a greater desire to compete in mathematics games in comparison to students who were not intrinsically motivated. Their findings also suggested that competitive games might engage poorer performing students by enhancing their motivation to play. However, Ryan and Deci (2000), key scholars in motivation theory and research, maintain that students who win can find competition motivating but for those who tend to lose, competition is likely to be discouraging. I return to a discussion of observations related to motivation and competition for my study in Chapter 5.

Studies into the effectiveness of GBL have considered several moderators which can play a role (Dondio et al., 2023). Dondio et al. indicated the nature of the game, whether digital or non-digital, the type of gameplay (multiplayer vs. single player), and the duration of the intervention all significantly impact their efficacy. In their meta-analysis of 154 studies, Talan et al. (2020) found non-digital games, which inherently promote multi-player interaction, to be more effective in reducing mathematics anxiety than digital games. Their findings suggest that non-digital games, given their design flexibility and opportunities for peer interaction, have larger effect sizes in reducing anxiety. They also noted the value of non-digital games in promoting interpersonal skills and adaptability in various learning environments. While the Talan et al. study did not exclusively focus on mathematics learning, their insights underscore the significance of non-digital games in diminishing anxiety, particularly in group learning settings, where their inherent abilities to facilitate face-to-face interactions can unfold.

The fusion of mathematics and games has been shown to allay mathematics anxiety for Grade 5 learners in Taipei (Chang et al., 2012). Other studies consistently reflect that game-based learning can enhance student motivation and academic achievement in mathematics (Clark et al., 2016). For instance, Huang et al. (2014), sought to determine the effectiveness of digital game-based learning (DGBL) for learning mathematics and examined students' mathematics anxiety, motivation to learn, and satisfaction with learning. The authors argue that diagnostic mechanisms embedded within digital games can provide students with more personalized and effective learning experiences. The participants of this study were Grade 2 (n=56) learners in southern Taiwan. This study included an eight-week learning activity with experimental and control groups. The experimental group used the DGBL system with the diagnostic mechanism, while the control group used the DGBL system without the diagnostic mechanism. The results indicated that DGBL with the diagnostic mechanism significantly improved students' learning outcomes and attitudes toward mathematics. The mathematics anxiety level of both groups was decreased by the DGBL system. The authors argue that the diagnostic mechanism was more helpful because it provides students with feedback.

In another study, Alanazi (2020) explored the effect of "active recreational mathematics games" (ARMG) that require physical exertion (e.g. sports, walking, dance) on 1st-grade male students' mathematics anxiety and performance. The sample was split into two groups; the experimental group (N=28) received instruction in mathematics using ARMG alongside traditional teaching methods, while the control group (N=30) was taught using traditional methods. Both groups were taught by the same teacher and were given pre-tests and post-tests to assess mathematics performance and anxiety. During the study, students attended three 45-minute sessions per week over a period of two months. The findings indicated that the experimental group scored lower on mathematics anxiety and higher on performance compared to the control group, which suggests that ARMG may be effective in improving student performance, reducing mathematics anxiety, and improving student attitudes toward mathematics.

Ng et al. (2022) studied the effectiveness of a digital training program in mathematics in reducing mathematics anxiety and improving skills in first and second-grade students in Taiwan. The study first evaluated 159 students' mathematics anxiety and its correlation with mathematics performance. A quasi-experimental design was applied, with 77 participants engaging in a computer-based mathematical game for six weeks. The results indicated significantly reduced mathematics anxiety in students after six weeks of intensive remediation.

Overall, the literature I reviewed suggests that GBL can have a positive impact on the mathematics attitudes of students in the elementary grades.

Teaching and Learning Fractions

Fractions, despite being a concept rooted in civilizations such as the Babylonians and Egyptians over 4,000 years ago, present substantial learning challenges in modern education (Gabriel et al., 2013). Gabriel et al. indicated that these challenges extend from everyday applications—such as estimating rebates and interpreting recipes—to advanced mathematics, such as probabilistic, proportional, and algebraic reasoning. Students struggle to learn fraction concepts, and teachers struggle to teach them effectively (Charalambous & Pitta-Pantazi, 2006). The multiple interpretations of fractions add a layer of complexity (Gabriel et al., 2013) to teaching and learning about fractions. From representing part-whole, ratios and operators to serving as quotients and measures, the multiple meanings of fractions (Kieren, 1993) can overwhelm learners, potentially heightening negative attitudes towards mathematics.

Given these struggles, lots of research has been done to understand how we can engage in better teaching and learning of fractions. One of the significant roadblocks in fraction understanding is referred as “whole number bias” (Ni & Zhou, 2005) where students mistakenly apply attributes and operations of whole numbers to all numbers including fractions (Siegler et al., 2011). For example, when adding two fractions such as $\frac{1}{2} + \frac{3}{4}$, a student might compute $\frac{1+3}{2+4} = \frac{4}{6}$. The misapplication of whole number thinking to fractions, which are rational numbers, creates confusion, especially if traditional learning methods fail to bridge this conceptual gap (Bonato et al., 2007). Understanding the conceptual differences between whole numbers and rational numbers is key to unravelling fractions (Gabriel et al., 2013). I believe that such challenges may further exacerbate feelings of inadequacy and negative attitudes towards mathematics among learners. I chose the concept of part-whole as the mathematical focus of the two games that I designed as these games may help to reduce the whole number bias that students often exhibit. In the rest of this section, I provide an overview of literature focused on the part-whole subconstruct of fractions as well as how this concept is included in the Manitoba mathematics curriculum.

The Part-whole Subconstruct of Fractions. Various researchers have highlighted the importance of understanding and mastering the part-whole sub-construct of fractions. Baturo

(2004), Boulet (1998), and Lamon (1999) have posited several foundational ideas for students to grasp concerning the part-whole subconstruct of fractions. Among the pivotal principles of this subconstruct is the necessity for equal-sized partitioning. Equal-sized partitioning is the idea that a whole unit or quantity can be divided into equal parts (Charalombos & Pitta-Pantazi, 2006). Students must not only recognize the equality of the parts but also be able to partition both continuous (often referred to as parts-of-a-whole) and discrete (often referred to as parts-of-a-set) units. For example, students need to be able to create a fair share, such as cutting one cake into six equal slices, ensuring that each person gets a piece of the same size and also be able to partition a set of 12 apples equally between four friends.

Charalombos and Pitta-Pantazi (2006) denoted that beyond mere partitioning, a deeper understanding of part-whole involves the connection between the individual sections and the whole. Firstly, the aggregate of the sections should account for the entirety of the whole. This implies that when a unit is segmented, the cumulative sum of the parts reconstitutes the original unit. Secondly, students must come to understand that the size of each part is inversely related to the number of divisions. That is, as one increases the number of partitions, each segment's size diminishes (Lamon, 1999). For instance, if working from the same whole, the size of the segment denoted by 1/5 will be larger than the size of the segment denoted by 1/20. Thirdly, despite size, form, arrangement, or orientation alterations, students need to understand that the proportionality between the parts and the whole remains invariant. That is, the constancy in the proportionality between the parts and the whole remains irrespective of alterations in size, form, arrangement, or orientation. For example, the proportionality of 1/2 is the same even when the total size of the object changes. That is, if you take half of a small cake or half of a large cake, each portion still represents 1/2 of its respective whole. This underscores the fundamental principle of 'inclusion' or 'embeddedness' in understanding fractions (Charalombos & Pitta-Pantazi, 2006). Students need to perceive individual sections as integral elements of the whole (Baturo, 2004). A gap in this perception can lead students to misinterpret fractions. These aspects of part-whole were considered as I created the two games for this study. However, the data gathered, and subsequent analysis do not focus on the extent to which students deepened their understanding of each aspect of part-whole but rather on their attitudes toward working with the part-whole aspect of fractions.

Part-whole Subconstruct in the Manitoba curriculum. Concepts related to part-whole fractions are included in the Manitoba curriculum standards across several grades. For instance, in Grade 4, students are expected to name and record the shaded and non-shaded parts of a whole or a set (Manitoba, Education, 2013, p.92.) and in Grade 5, students are expected to 'create sets of equivalent fractions' which requires a deep understanding of part-whole (Manitoba Education, 2013, p.103). Table 1 includes an overview of specific learning outcomes and the suggested achievement indicators in the Manitoba curriculum standards which relate to the part-whole understanding of fractions. I have focused on Grade 3, Grades 4 and 5 in this table because I conducted my study in a Grade 4 classroom. In the next section, I describe how the games I designed are intended to reflect these curriculum outcomes.

Table 1: Part-Whole Fractions Curriculum Overview for Grade 3, Grade 4 and Grade 5

Grade 3	
Specific Outcomes	**Achievement Indicator**
· explain a fraction represents a portion of a whole divided into equal parts · compare fractions of the same whole with like denominators	· Cut or fold a whole into equal parts or draw a whole in equal parts; demonstrate that the parts are equal and name the parts. · Compare fractions with the same denominator using models.

	• Identify the numerator and denominator for a fraction. • Model and explain the meaning of numerator and denominator.
Grade 4	
Specific Outcomes	**Achievement Indicator**
• name and record fractions for the parts of a whole or a set • compare and order fractions • model and explain that for different wholes, two identical fractions may not represent the same quantity	• Name and record the shaded and non-shaded parts of a set. • Name and record the shaded and non-shaded parts of a whole. • Represent a fraction pictorially by shading parts of a set. • Represent a fraction pictorially by shading parts of a whole.
Grade 5	
Specific Outcomes	**Achievement Indicator**
• create sets of equivalent fractions • compare fractions with like and unlike denominators	• Create a set of equivalent fractions and explain why there are many equivalent fractions for any fraction using concrete materials. • Model and explain that equivalent fractions represent the same quantity. • Determine if two fractions are equivalent using concrete materials or pictorial representations. • Formulate and verify a rule for developing a set of equivalent fractions. • Identify equivalent fractions for a fraction. • Compare two fractions with unlike denominators by creating an equivalent fraction

Note: Adapted from Manitoba Education (2013)

Connecting Each Game to the Literature and Curriculum

According to mathematics education literature, there are specific strategies that can enhance the teaching and understanding of fractions (Bruce & Ross, 2009). I believe that

Tombamath and the Fraction Story Game include many of these techniques (see Appendix A for additional details of each game). The games use visual representations such as segmented circles, groups of objects, and manipulatives, to provide students with concrete representations of fractions, a technique emphasized in educational literature for its efficacy (Bruce & Ross, 2009; Butler et al., 2003). Additionally, I designed the games to promote active participation, a crucial component in enhancing student engagement and understanding, as highlighted by the National Council of Teachers of Mathematics (NCTM, 2014) and in constructivist learning theory. Instead of just listening, students are constantly matching, thinking, and engaging, making their learning experience more active and meaningful. Furthermore, by playing in groups, students can collaborate, discuss, and reason together, which fosters a richer mathematics learning environment according to NCTM (2014). Lastly, the reflections after the games are intended to ensure that students think about fractions in a broader context, connecting their learning to bigger ideas and real-world scenarios (Bruce & Ross, 2009; Naiser et al., 2004).

In the Manitoba Curriculum (2013), there is a significant emphasis on ensuring that students grasp the fundamental concepts and relationships tied to fractions. I designed these games to be aligned with this curriculum and with the intent to provide an immersive and hands-on approach to understanding fractions. In Tombamath, by integrating fraction cards with diverse visual representations on the game cards, the game can create a direct bridge to the curriculum objectives around understanding, representing, and distinguishing between different fractional parts. When a fraction is announced by the teacher, students are faced with the challenge of identifying its concrete representation, fostering an environment of active recall and application. This dynamic not only covers the aspect of recognizing parts of a whole, such as is represented in segmented circles, but also extends to understanding parts of a set, as represented by groups of objects on the game cards.

The Fraction Story Game provides students with an opportunity to understand the complicated concepts of fractions in a practical and engaging way in keeping with the goals in the Manitoba Curriculum standards (2013). Through the game's scenarios, students gain hands-on experience in representing, comparing, and understanding the part-whole relationship of fractions. The real-world contexts offered by the game scenarios, such as pizzas and chocolate bars, resonate with the curriculum's emphasis on real-life fraction applications. Moreover, by using diverse manipulatives, students can visually represent these abstract concepts, as required in the curriculum standards. Furthermore, the game encourages students to actively communicate their understandings, fostering connections between mathematical ideas and real-world applications. Each scenario card also acts as a problem-solving prompt, aligning with the curriculum's problem-solving goals. The game's format allows students to reason out their choices, encouraging logical thinking.

Comparing Tombamath and the Fraction Story Game reveals differences in their instructional approaches. Both games are conducted in-person and foster collaboration, yet they diverge in their methods and objectives. Tombamath relies on within-group collaboration for matching fractions with visual representations through cards, fostering a competitive environment with a focus on mathematical skills. Conversely, the Fraction Story Game prioritizes collaboration through group discussion, aiming to concretize abstract concepts using real-world scenarios. Unlike Tombamath's competitive rounds, the Fraction Story Game features a collaborative exploration of real-world scenarios with manipulatives, intended to ensure that each group has the opportunity to engage fully in the learning process. Another key difference is that Tombamath asks students to recognize representations of fractions whereas the Fraction Story Game asks students to create representations of fractions. Moreover, while Tombamath's game ending is determined by the first group to fill their bingo card, the Fraction Story Game follows a cycle until all groups have utilized each of the available manipulatives (i.e. fraction circles, fraction tiles, unifix cubes, and number lines). These distinctions highlight varied approaches to learning fractions, emphasizing the importance of understanding how students experience and engage with different instructional approaches.

The Manitoba Curriculum standards (2013) underscore the importance of mathematical processes including communication, connections, problem-solving, and reasoning. I believe that Tombamath and the Fraction Story Game effectively integrate these processes. Although the dimensions of part-whole and the ways that the processes are enacted differ between the games, students are encouraged to engage in mathematical dialogue, reason out their choices, work with diverse visual representations of fractions, and solve the problems presented by making connections between abstract concepts and concrete representations.

Notably, the observations from this study focus on students' affective responses to each game in relation to some of the design features of the games. It is important to show the connection between each game and the Manitoba curriculum standards as part of the context for the study. However, the data gathered in the study does not provide insights into the impact of each game on students' conceptual learning of fractions.

Chapter 3: Methodology and Research Methods

In this study, I employed a qualitative research design (Merriam & Tisdell, 2015) to explore and understand the experiences, perceptions, and attitudes of Grade 4 students and their teacher regarding GBL and learning fractions. I examined the two games by observing students in gameplay sessions with the full class, inviting students to respond to a short questionnaire related to each game, interviewing their teacher before and after the gameplay sessions, and video recording a group of eight students as they were playing each game. I chose to use a qualitative methodology that included several data sources because the primary goal was to explore in depth these students' experiences as well as their teacher's perspective regarding GBL and learning fractions. A qualitative methodology is suitable for this purpose because it enables researchers to capture participants' experience and can provide detailed insights into their perspectives (Merriam & Tisdell, 2015).

This methodology also aligns with the constructivist view of learning which emphasizes that learners construct their own knowledge from their experiences and interactions with their environment (Vygotsky, 1962; Piaget, 1980). Similarly, qualitative methodology can enable researchers to observe how people perceive and interpret their experience in their natural learning environment (Merriam & Tisdell, 2015). It is also a good fit with self-efficacy theory because it can provide opportunities for a researcher to more deeply explore students' perceptions of what they can achieve with their skills or capabilities (Ahmed & Jabeen, 2011). Moreover, this methodology resonates with game-based learning theory since it allows for an in-depth exploration of students' experiences during gameplay. According to Piaget games are effective learning environments because they offer collaborative learning, feedback, real-life scenarios, and reflection, which can impact learners' engagement, understanding, and overall educational outcomes (Zhong, 2019). A qualitative methodology is ideal for capturing these experiences. In this chapter, I detail the research methods, including ethical considerations, data collection and analysis.

Ethical Considerations

This study posed minimal risk to the participants. I followed the ethical considerations of the Tri-Council policy on research involving human participants (CIHR, NSERC & SSHRC, 2022). In line with “Respect for Persons”, I ensured that participants were treated with dignity and autonomy including informed consent for the teacher and parental consent and assent for the children. “Concern for Welfare” was a paramount focus and I endeavoured to maximize the benefits and minimize the potential harms to participants. For instance, I ensured that the games align with the curriculum so that time spent playing them did not detract from students’ learning. Ethics was approved by both the University of Manitoba Research Ethics Board (see attached Approval Certificate in Appendix D) and the research ethics procedures established by the participating school division.

Participants

The participants were students in a Grade 4 classroom as well as their teacher. They were from an elementary school in Manitoba. The choice of classroom was influenced by the willingness of the district and school administration to participate in the study, as well as the teacher's interest in participating in the study. Consent and assent forms were sent home with children. Only students with consent and assent were able to participate in the study. A total of 13 students in a class of 28 students submitted both consent and assent forms prior to the first day of data collection. All students in the class engaged in the full-class gameplay sessions as part of their regular mathematics class but my observations for the study were limited to those students who provided assent and consent.

Data Gathering

Various data sources were gathered to gain insights into the research questions. These data sources include: two audio-recorded teacher interviews (one before the gameplay sessions and one after the gameplay sessions); the written observation notes I made during the gameplay sessions with the full class; students' responses to the questionnaires; and video recorded observations of a group of eight students as they played each game. In this section, I describe each data source in greater detail.

Teacher Interviews

I conducted semi-structured interviews with the classroom teacher. Both interviews were conducted in person. The purpose of first interview, prior to the gameplay sessions, was to gain an understanding of what the teacher thinks is important in game design for students as well as how she uses games in her mathematics classroom. The second interview, after the gameplay sessions, focused on gaining insights into the teachers' perspective on students' behaviour and engagement as they played each game. Both interviews were audio recorded and transcribed. The first interview was 22 min 3 sec long and the second interview was 25 min 24 sec long. The interview protocol that guided each interview is included as Appendix B.

Observation Notes from Full-class Gameplay Sessions

For the full-class gameplay sessions, the students played each game three times during a one-week span. Each gameplay session took place in the students' regular classroom and lasted about 30 minutes. In the first week (December 9-11), they played Tombamath on three occasions and in the second week (December 17-19) they played the Fraction Story Game three times. The teacher facilitated these gameplay sessions while I sat at the back of the classroom to observe and make notes about students' reactions, engagement levels and behaviours as they played the games. I limited my observations to those students who provided assent and consent. The teacher provided me a class list indicating which students had assent and consent. Students had name tags on their desks which allowed me to easily identify each student and record observations only for those with consent and assent.

When they played Tombamath, students were seated in groups of four or five students. The teacher grouped them strategically, according to whether the students typically worked well with one another or did not. The bingo cards were distributed, and the teacher drew the fraction cards from the bag. She announced each fraction as groups of students sharing a bingo card looked for a representation of the fraction on their card. When they played the Fraction Story Game, students were seated in groups of three or four. The manipulatives that each group had were different and in each round of gameplay they switched the manipulatives that they had. I provide more details about how the full-class gameplay sessions for the two games unfolded in Chapter 4.

Student Questionnaires

After the third gameplay session in each week, I administered a short questionnaire to the students (Peterson, 2000). The first questionnaire consisted of four open-ended questions and one selected-response question focused on students' perceptions and feelings about Tombamath while the second questionnaire included the same five questions focused on the Fraction Story Game as well as an additional question asking students which game they preferred (see Appendix C). Through the questionnaires, I aimed to gain some general insights into students' views of the design of the game, their level of engagement, and the impact of the game on their feelings about mathematics. I distributed the questionnaires to the students and briefly explained the purpose of the questionnaire and how they should complete it. We read each question together to help the students understand more fully and then students had about 20 minutes to complete the questionnaire. All students were asked to complete the questionnaires but only the responses of students who had provided consent and assent were included in the study. Although 13 students provided consent and assent, I collected 12 responses for each questionnaire because on the days when the questionnaires were administered, one student who had provided consent and assent was absent. As described in Chapter 4, students tended to write fairly short responses to the questionnaire items which sometimes made it difficult to understand what they were expressing.

Video Recordings of Small-group Gameplay Sessions

After the full-class gameplay sessions, I conducted a video recorded observation of students playing the two games. In this session, eight fourth-grade students were chosen as participants from among the 13 students who had provided consent and assent. The teacher chose the students for the small-group session based on which students work well with one another. The video recorded gameplay session took about 35-40 minutes to set up and complete, and the videorecording is 26 minutes long. The same group of eight students played both games. They played Tombamath first and then played the Fraction Story Game. Although these eight students answered the questionnaires from the full-class gameplay sessions, I was not able to link questionnaire responses to individual students. During the session, I video recorded the group from two different angles. I aimed to create a comfortable and familiar environment for the students, while gaining insights into their experiences, reactions, engagement, and interactions as they engaged in each game. Since I was facilitating the small-group gameplay session, I did not make observation notes during this part of the study.

Data Analysis

My analysis of this data is based on the thematic analysis approach outlined by Guest et al. (2012). Their framework provides a systematic approach to identifying, analyzing, and reporting patterns or themes from data. Their approach includes identifying themes or recurring patterns, developing codes, and analyzing data by comparing code frequencies, recognizing code co-occurrence, and displaying relationships between codes within the dataset. I conducted three rounds of analysis of the data. The first round consisted of analysing individual data sources. In the second round, I considered the data across data sources. In the third round, I considered the themes that had emerged in relation to each research question. During each stage of the analysis, I discussed the sub-themes and themes that I saw in the data with my advisor. We also discussed some aspects of the data that my advisor interpreted a little differently in light of her familiarity with the Canadian elementary school context. The themes that I identified in each round of the analysis emerged from the data to some extent, but they were also influenced by aspects of GBL, constructivism, and self-efficacy. In this section, I describe the analysis process and identify some of the main themes that emerged. I provide a detailed description of the observations and findings in Chapter 4.

First Round: Analysing Individual Data Sources

In the first round, I started with the student questionnaires which provided an overview of students' experiences with the games. Their responses to questionnaire items were relatively short but I was able to identify some initial patterns in the data. I started with organizing and reading through the questionnaires to become familiar with them. Then, I created separate data tables for each questionnaire. In each table, I identified sub-themes from the students' responses and then grouped these sub-themes to develop main themes. Some examples of the main themes that emerged during this process include cognitive benefits, engagement and fun, luck factor, emotional reactions, and game mechanics and tools. I implemented this process separately for each questionnaire and created one theme table for each questionnaire with supporting evidence from the students' responses. Afterwards, I combined the two theme tables into a single table with a separate column for each game. This allowed me to more easily compare the responses for the games.

Next, I analyzed the initial and follow-up interviews with the teacher. I started with reading through the transcripts and then wrote a summary of each interview question-by-question before combining these summaries to create a comprehensive summary of each interview. I used direct quotes from the transcript to support my summary. I carried out this process separately for each interview. Then, I identified sub-themes from the summary and wrote the definition of each sub-theme to clarify my understanding of the data as I was coding it. Afterwards, I grouped the sub-themes into main themes and created a table with these themes that included examples of supporting evidence (i.e., quotations) for each theme. Some of the main themes that emerged from this process were game competition and luck factor, game difficulty and accessibility, game flexibility and adaptability, engagement and fun.

With the themes from my analysis of the student questionnaires and the teacher interviews in mind, I analyzed my observation notes from the full-class gameplay sessions. I started with reading through the notes to become familiar with them. Then, I created a table where I coded the observation notes sentence-by-sentence. Then, I organized the codes to create meaningful groups which became the main themes for this data source. I carried out this process separately for my observation notes for each game. I prepared a single table for the observation notes with a separate column for each game, adding supportive examples for each theme into the table. In this way, I was able to compare and interpret the similarities and differences between the games more clearly.

As the final stage in the first round of analysis, I analyzed the video recording of the small group gameplay session to gain more insights into students' experiences as they engaged with each game. I started by watching the video many times to become familiar with the data. Then, I wrote a summary of the events that unfolded in the video. While watching, I paused the videos minute-by-minute and wrote a summary of what was taking place, trying not to miss any details. Then, I read through the summary I had written and coded sentence-by-sentence according to the sub-themes I noticed in the data. I organized these sub-themes into meaningful groups, allowing me to identify the main themes. Some of the main themes that emerged in this process were emotional reactions to game, engagement and participation, collaboration and peer interactions, competition and game driven motivation. I conducted this process separately for the summary of the small-group gameplay session for each game. Afterward, I compared the themes from both games to identify similarities and shared patterns. Based on this comparison, I created a single table for the video recording with a separate column for each game and examples to illustrate each theme.

Second Round: Reconsidering Themes across Data Sources

In the second round, I revisited the theme tables from the video recording. At this stage, I checked for any overlaps between themes within the table and adjusted if necessary. Then, I carried out the same process for the observation data. I made some changes to the themes table in order to remove a few overlapping themes. Then, I noticed that the themes from the video recording data were quite similar to the themes from the observation data. Taking these similarities into account, I named the matching themes from both data sources using the same terminology. This allowed me to highlight similarities and differences between the different data sources. I applied the same process for the interview and questionnaire data. I organized these data as well, making the theme tables more meaningful and structured. I re-labeled those themes that matched other sources using the same theme name. This allowed me to see similarities and differences across the data sources.

With regard to linking observations of participating students with their questionnaire responses or with other observations, I did not record specific student names or identifying information during my classroom observations. Similarly, although all students wrote their names on the questionnaires, their names were removed during data analysis once I had extracted the questionnaires that were completed by students who had given assent and consent. Therefore, I could link students across the two questionnaires but not from the two questionnaires to the other data sources.

Third Round: Revisiting Themes in Relation to Research Questions

After re-organizing the theme tables in the second round, I chose one colour for each research question. Then, I went through all the theme tables and marked each theme using colours according to the research question to identify themes that related to each question. Some of the themes related to multiple research questions (e.g., the theme “Competition and Game-driven motivation” related to Research question 1 as well as Research Question 2 whereas the theme “Level of challenge” only related to Research Question 2. To increase the reliability of the data analysis, I completed the third round of analysis by once again reviewing the themes and subthemes with my advisor in relation to the research questions.

Chapter 4: Observations and Findings

In this section, I present the observations and findings of the study. First, I provide a summary of the observations from each data source. Then, I present the results in relation to each research question, organized according to the main themes which I identified in my analysis.

Summary of Observations from Each Data Source

Questionnaire 1 – Students' Views of Tombamath

Questionnaire 1 consisted of five open-ended questions which focused on students' feelings and experiences with playing Tombamath. There were 12 questionnaire responses for this game. The first question was, "What did you like about this game?" For this question, although students' responses were varied, most of them were positive. For instance, two students reported that the game was fun and interesting while one student specified what they liked about the game was having winners at the end of the game. Two students also stated that including teamwork was one thing that they liked about the game and one student indicated that they liked it "because it was like bingo." Moreover, some participants stated that the game was not only fun but also educational. Three students specified that they enjoyed learning about mathematics and fractions. For instance, one student indicated that he liked this game because "it makes u smart."

The second question was, "What did you not like about this game?" Five out of 12 responses to this question were "nothing". This suggests that these students had a positive experience when playing this game, but it may also indicate that students didn't want to say something negative about the game. On the other hand, four students expressed that they didn't like the fact that winning this game was based on luck and one student stated "I don't like the math". It is not clear if this comment was specific to the mathematics concepts or processes in this game or to mathematics learning more generally.

The third question was, “Where there moments in the game that made you feel anxious or stressed? If yes, can you specify what made you feel like this?”. I rephrased this question as “How did you feel while playing the game?” when I administered the questionnaire to the students. I made this revision because I realized that the question was difficult for students to understand and because some of the response options were positive emotions which did not match the question stem very well. The question included selected response options and students could select as many responses as they wished. The frequency of responses from the 12 participants was: Confusion (6), Curiosity (2), Confidence (4), Excitement (4), Joy (4), Frustration (2), Engagement (1) and Boredom (2). Thus, half of the students checked confusion as one of their responses while a third of the students indicated confidence, excitement, or joy. This pattern of responses suggests that the students had varied perspectives on the game, since six chose confusion, while four chose confidence. However, it may also suggest that students had difficulty reading the response options or were not clear on the meaning of some of the words. For these reasons, I found that this question had limited value in eliciting how students felt while playing the game.

The fourth question was, “After playing the game, have your feelings or attitudes toward fractions or doing mathematics changed in any way? Please explain.” Six students specified a positive change in their feelings toward mathematics particularly fractions, after playing this game. Five of these six students mentioned that the game helped them learn fractions and also contributed to feeling better about mathematics overall. For instance, one student, who wrote on an earlier question that they did not like mathematics, expressed feeling more positive about fractions and being better at mathematics after playing this game. This student wrote, “I felt pretty good after I did it, I felt like I got better at math and fractions.” Additionally, one student said the game was fun, which improved their feelings toward mathematics. However, four students reported no change in their feelings after playing the game, while one student mentioned feeling upset when they couldn't win the game stating, “Sometimes when I do not win I feel sad and mad.”

The fifth question provided students the option to offer “Additional comments.” Nine students stated “nothing” while two wrote that the game was based on luck. One student said, “I think the game should be one person” perhaps meaning that they would prefer to have their own Tombamath card rather than play with a group.

Questionnaire 2 – Students’ Views of the Fraction Story Game

Questionnaire 2 consisted of the same five questions as Questionnaire 1 and an additional question which asked students which game they liked better. I received completed questionnaires from 12 of the 13 students who submitted consent and assent forms. The first question was, “What did you like about this game?” Students generally indicated that the Fraction Story Game was enjoyable, educational, and effective in teaching fraction concepts. Six of them reported that the game provided an opportunity to learn something new about fractions, helped them better understand fractions or improved their mathematics skills. Three participants noted that they liked the manipulatives that were used in the game (unifix cubes, fraction strips, and questions). In addition, one participant expressed overall appreciation writing “Yes, because the game is good.” However, one student stated that they didn’t like anything about the game. This student had also stated in Questionnaire 1 that they didn’t like mathematics.

The second question was “What did you not like about this game?” Four out of 12 responses to this question were “nothing” while three students mentioned that this game was too hard, and they struggled to understand the questions and found the game boring. For instance, once student wrote “Can get boring fast/can be too hard”. Two students stated that they disliked the fraction circle manipulative used in the game, “I didn’t like the circles.” One student specified that they didn’t like making fractions stating, “Making fractions”. As mentioned previously, in the Fraction Story Game, students create representations of fractions whereas in Tombamath they need to recognize representations of fractions thar are on their game card.

For the third question, “Were there moments in the game that made you feel anxious or stressed? If yes, can you specify what made you feel like this?”, I again rephrased the question as “How did you feel while playing the game?” when I administered the questionnaire to the students. The frequency of options for the students chose was: Frustration (4), Confusion (6), Excitement (6), Joy (8), Curiosity (2), Confidence (8), Boredom (4), Engagement (2). Here again, it may be that individual students had different perspectives on the game with some finding it frustrating, confusing and boring while others felt confident and excited. It is also notable that students selected more options for this question than they did on the first questionnaire (i.e. a total of 40 options were chosen on the second questionnaire whereas a total of 25 options were chosen on the first questionnaire, with 12 students responding each time). Since several individual students selected numerous and diverse emotional options, I was able to learn only a limited amount from this question. As noted for Questionnaire 1, it is also unclear how well the students understood the meaning of each response option.

The fourth question was “After playing the game, have your feelings or attitudes toward fractions or doing mathematics changed in any way? Please explain.” Six children stated that the Fraction Story Game changed their feelings and attitudes towards mathematics positively while three of these six students reported that they learned new concepts about fractions as well as improved in fractions. One participant indicated that the game made mathematics enjoyable stating that “Yes because it makes math fun”. At the same time, three of the participants reported no change in their attitudes and one student said that game caused stress stating, “No because it made me too stressed”. These results suggest that individual students respond to or experience the game in different ways.

The last question was “Which game do you like more: Tombamath or Fractions Story? Why?”. One participant indicated that they liked both games while six out of 13 specified that they liked Tombamath game. Their reasons for preferring Tombamath included that it was more like bingo, more exciting and more fun. They used phrases such as “Tombamath because the bingo part is more fun”, and “Tombamath because I like bingo because it’s fun”. On the other hand, five participants stated that they liked the Fractions Story Game more. Their reasons for preferring the Fractions Story Game included that it led them to think about fractions and “Fraction stories – I like something that I had to think more” and “Fraction stories cuz I was bad at it and now I know it”. Responses to this item suggest that neither game is more strongly preferred by this group of students and that the reasons for preferring each game may be unique to each student. I discuss these observations more extensively in relation to the research questions later in this chapter and in relation to the literature in Chapter 5.

The final question asked for “Additional comments.” Nine students wrote “nothing” while two students wrote that it was boring, and one wrote “very good”.

Initial Teacher Interview

In the initial interview with the teacher, while talking about students’ attitudes towards learning fractions, she expressed the view that learning fractions is “quite hard” (line 10) for students. She explained that, in her opinion, the formal introduction to fractions takes place in Grade 4 and that the Grade 4 learning objectives are different from what students have previously learned. She stated, “They have a little bit of a freak out when they first have to do a fraction because they've never seen it before and don’t know what it is” (lines 17-18). She also noted that there are some specific challenges that students encounter while learning fractions. She noted that since they have only worked formally with whole numbers prior to Grade 4, they need to figure out what the top number and the bottom number in a fraction mean and once they do that she explained “their comfort level gets a bit better” (line 27).

During the interview, I also asked some questions about her sense of children’s mathematics anxiety in her classroom. She explained that many of the students have a hard time with “early skills of counting and basic counting facts” (lines 41-42) and that those who are missing these early skills have more mathematics anxiety. She uses various strategies to try to develop these early skills and help to reduce mathematics anxiety. She explained that when students are completing assessments of their fact fluency or working on new concepts, she encourages them not to compete with one another. For instance, she tells the students:

> We are going to remember some of us might do this quickly. Some of us might take more [time]. It's because some of us have had more practice. Some of us haven't had as much practice. Everyone's just gonna do their best. And yeah, when we're doing facts or counting you know or anything like [where] they need that speed, it's like well, our goal is to beat our score from last time. Our goal isn't to worry about what our neighbors are doing. (lines 77-83)

The teacher explained that these are some of the ways that she tries to build each student’s self-esteem.

I also asked questions about integrating games into her mathematics classrooms. She described the ways that she uses games to reinforce learning rather than to introduce a new topic.

She stated that “The game is more for reinforcement. So, I don't usually start anything with the game until they know what the thing is” (lines 100-101). She also uses games as a reward for students who have completed other work or when she wants to give students a break from more challenging work. She noted that she has a game box in the classroom with a variety of strategy games such as adding, subtracting, and multiplying games. There are also one-player or two-player games in the classroom that students can play and sometimes the whole class plays a game together.

When I asked about potential benefits of games as a teaching tool, the teacher told me that she should probably use games more often in her classroom since the students enjoy playing games. On the other hand, she was concerned that using games as an assessment tool, even as a formative assessment tool, may be insufficient because some students may be playing the game as a leisure activity and may not be focusing on the concepts they are supposed to learn. In addition, she noted that some students may struggle to understand the game and need an adult to assist them. However, there are not always enough adults in the classroom to provide this assistance.

The next question was about making a game an effective tool for learning, the teacher noted that “it needs to be simple enough so that the kids can get it easily.” (line 189). At the same time, she explained that when you have a diverse group, some students may catch onto the game quickly and get bored while other students may struggle. She continued to discuss other aspects of game design in relation to mathematics teaching such as different grouping strategies that might be used during gameplay sessions. She also discussed some of the ways that she might facilitate the full-class gameplay sessions with each game in the study. Near the end of the interview, she returned to the topic of how gameplay might be successfully integrated into her approach to mathematics teaching. I provide a more detailed discussion of the teacher's views of the design and use of mathematics games in my discussion of Research Question 2.

Follow-up Teacher Interview

In the follow-up interview, I began by asking the teacher to describe in general her students' attitudes about mathematics learning. In her response she described a range of student attitudes within the class including "a handful of students that are really keen" (line 14), a group of students "in the middle that kind of you know, they'll do it because they have to and they know it's math time but often need encouragement to keep going" (lines 14-16), and some students who "just need a lot of support to get going" (lines 25-26). She also explained that even among the students who are struggling, she did not notice significant mathematics anxiety in this group of students, unlike students she has worked with in previous years. In addition, the teacher described how some the students who are struggling with mathematics learning may engage with mathematics learning more actively if they have an opportunity to work with a different group of students in the class.

The teacher expressed her overall impression of the student's engagement with Tombamath. She noted that most of the students "were quite engaged" (line 63), especially during the first of the three gameplay sessions. She also mentioned that the game might have been more engaging if the number of students in each group was between two and four students rather than five or six students working with one bingo card. She stated, "it would probably have been beneficial to have smaller groups only just so that there were more eyes focused on the game board at once." (lines 66-67). She also pointed out that there were a few students who were not engaged and "were I think on purpose trying not to look . . . because they didn't care or they just didn't really want to be involved or maybe it wasn't their friends [in their group]" (lines 75-

76). She described the way that two students who were learning English engaged with the game and mentioned other forms of mathematics-focused bingo that she had used in her classroom (i.e. clock bingo, adding and subtracting bingo).

I also asked the teacher to share her impression of the impact of each game on the class dynamics. With respect to Tombamath, she stated “the first game I would say was positive because they were all trying their best to win” (line 109-110) although she noted that some students complained about not winning or having an unlucky card. The teacher also noted that she finds that no matter what game the class plays, some students complain about not being winners. At the same time, she stated that having winners at the end of the game boosts their engagement and she noted, “if the engagement kind of outweighs that [the complaints about not winning] you know, then I think you're in the right direction.” (lines 122-123). With regard to the Fraction Story Game, the teacher stated that it was more difficult for students because they needed to read and make sense of the questions and some of the questions included multiple steps. She mentioned that it was difficult to check in with every student and therefore hard to tell who fully understood the concepts. In addition, she noted that students found the questions that involved fractions as part of a set more difficult than fractions as part of a whole.

When asked to compare student behaviour or engagement between the two games, at first, she commented that there wasn’t any noticeable difference but as she continued speaking, she identified some differences. For instance, she noted that students started out more quietly when playing Tombamath, but they got louder as some students became more engaged, and others got restless or bored. The teacher emphasized the need to keep activities fresh to hold students' interest and explained ways that the gameplay was changed a little from session to session with this in mind. Overall, she felt that Tombamath seemed to engage students more than the Fraction Story Game. She indicated that the engagement probably came mostly from being excited about winning but that it might also be related to trying to figure out the right answer or wanting to help their group. She also noted that when prizes are involved this boosts engagement stating, “I know there's too many reasons sometimes about why they may or may not be [engaged], but the competitive piece definitely they like that . . . and when there's prizes, they're even more competitive” (lines 264-268).

When asked if she noticed any changes in students’ attitudes toward mathematics during the gameplay sessions, the teacher initially stated that she did not notice any changes though she noted that this may have been because she was focused on facilitating the gameplay sessions. As she continued speaking, she noted that some students initially found the Fraction Story Game difficult but when they started to understand it better, through help from her or from their peers, they became more engaged. Overall, she emphasized the value of engaging students in games or other activities, highlighting how this helps their learning and is more engaging than pencil and paper tasks. She commented that none of the students gave up or had “a temper tantrum” (line 303) during the gameplay sessions and saw this as evidence that the sessions were a positive experience.

I was interested to note that the teacher described how integrating games into her mathematics curriculum can benefit student learning but she also stated that she believes that there needs to be both gameplay and pencil and paper tasks. She focused on the importance of integrating various approaches to teaching, stating “I think the more variety you even have in your math class, the better. So, it's not just pencil and paper. It is not just games. It's not just working with a partner; it's not just working in a group and doing math centers. Yeah, it's all of those*"* (lines 391-393). I share more insights about the teacher's views of the use and design of mathematics games in the observations related to Research Question 2.

Observation Notes from Full-class Gameplay Sessions

In my observation notes from the first gameplay session with Tombamath, I noted that the game was met with excitement and most students were eager to participate. The teacher explained the game and the rules and used questioning to remind students of different kinds of fractions and their representations. The teacher then grouped the students according to whether they usually work well with one another or not so well. She also tried to group students who performed well with students who were struggling to create a learning environment where everyone could benefit from working together. However, I noted that some of the students complained about their group because they wanted to be with their friends. During gameplay, most of the students were working actively, although some students were more active than others as they discussed and justified their answers while others just listened to other students explain their thinking. I also noted that mixed fractions led to hesitation for some students. Generally, students were excited during the game and wanted to win. This seemed to keep them motivated and also seemed to cause strong emotional reactions when they won or lost. For instance, I noted that even if they were distracted during gameplay, when a new fraction was drawn, they came back to the game because they wanted to win saying "We will win" or "Only one left". When one group finished first, they shouted "Bingo!" with great enthusiasm. However, the other groups were not as pleased with the outcome, expressing their frustration by saying, "That's not fair". I also heard some students complaining that the game was all about luck. Interestingly, none of them expressed negative attitudes toward fractions or mathematics during the game, even though the teacher had noted in her initial interview that some of them struggle with fraction concepts.

In the second gameplay session with Tombamath, students were happy to play the game again, but I noted that they showed less excitement than in the first session. Before the game started, students expressed their preferences for the group they would be placed in. Some students didn't want to be in the same group as they had been in on the previous day. Once the groups were formed, students focused on the game and discussed the fraction representations with their group members. I also observed that students who were more active during the first gameplay session were again more active than others in the second gameplay session. However, I noted a change in one previously passive student, who became highly motivated by the possibility of winning during the second gameplay session saying "We are close! We're going to do Bingo!". I also noted that the gender distribution within groups appeared to influence students' interest in the game. For instance, I saw that in some cases when there were more boys in a group, the girls did not fully participate but when there were more girls in a group, the boys seemed to be less active. I also noted that mixed-gender groups in the classroom seemed more interested in the game as compared with single gender groups and that students seemed more easily distracted and lost interest in the game more quickly in single-gender groups. Overall, this second gameplay session was quite competitive with frequent shouts of "bingo" as well as some false declarations of bingo. I also noted that the same group won during the second session as had won in the first gameplay session.

In the third gameplay session with Tombamath, I noted that students initially showed excitement, but their enthusiasm dropped when they learned they would be playing the same game again. There was a substitute teacher for this third gameplay session because the classroom teacher was away. The substitute teacher mixed up the groups to change the group dynamics and this again led to some complaints among students. Compared to the previous sessions, I noted there was an increase in distracted students, but their motivation to win again seemed to motivate them throughout the game. I noted that some students said that they wanted to change groups to join the group that had previously won. Overall, I noted that most students seemed to focus more on winning than on learning fractions and that student behaviour was consistent with previous sessions.

In the first gameplay session with the Faction Story Game, I noted that while students were excited about playing a game, when they heard that the topic was fractions, most of the class was unhappy and at least one student reacted by saying, "I hate fractions!". In the Fraction Story Game, students need to represent and solve real-world problems using four different manipulatives (fraction tiles, fraction circles, unfix cubes and fraction number lines). The teacher let the students select their groups and most students seemed to form a group with their friends. However, I noted that working with friends led to distractions for some students since they talked to each other or played with manipulatives instead of focusing on the game. While some students played actively, others were off-task and making noise. I also noted that the same students who were more active in Tombamath were more focused during this game as well. The Fraction Story Game requires different mathematical skills than Tombamath and I noted that many students struggled with reading the questions during this first gameplay session. Some students appeared stressed, as they displayed behaviours such as bouncing their legs, wringing their hands, and glancing around nervously. I also noted that some students seemed to gain confidence after solving a few problems with help from the teacher.

In the second gameplay session with the Fraction Story Game the teacher changed the way she facilitated the gameplay. She divided the students into groups based on their birthdays and then formed a large circle in the classroom. The teacher stood in the center of the circle so that she could easily see all the students. Each student took a question from the bag and was given time to solve the question and demonstrate the solution using a manipulative. I noted that the class was quieter than the first time they had played the game and that even though some students were still not focused on the questions, most of them were trying to solve the questions. During this session the teacher also let each group choose the manipulatives they would use to represent the question. I noted that this seemed to make students quite happy. Again, I noted that some students took a more active role in some groups during this process, while others remained more passive. Interestingly, these passive students were usually the students who showed a similar attitude when playing Tombamath. In this gameplay session, even though many students seemed to be engaged in the game, their attention seemed to fade when their turn passed. Once they shared their answers, it seemed as though the game felt over for them.

In the third gameplay session with the Fraction Story Game, I noted that there were no changes in the rules or way of facilitating the start of the game. However, this time, the teacher implemented a new strategy in an effort to keep the students engaged at the end of the game. She asked them to write their own fraction story questions. Although not all students participated with the same level of enthusiasm, writing their own questions seemed to help them to remain attentive to the game. While some students eagerly competed to write more questions—saying things like, “I wrote more questions!” others seemed to find the task intimidating and were unsure of what to write. Overall, the teacher made more changes in the ways that she facilitated the Fraction Story Game than she did in the way that she facilitated Tombamath. I provide more observations about students' experiences with each game when I discuss the observations in relation to each research question.

Summary of Observations from Video Recordings of Small-group Gameplay Sessions

The video data provides moment-by-moment evidence of how a small group of students engaged with each game. In this section I provide an overview of how the gameplay unfolded for each game. I share more details from the video recorded small-group gameplay session when I describe the findings in relation to the research questions later in this chapter.

Summary of Video of Small-group Play for Tombamath. There were eight students seated around the rectangular table for this session which took place in a small classroom. Each group of two students shared one bingo card. I informed them that we were starting the game and first drew the fraction '2/3' from the bag. I stated the fraction by saying "two thirds" and then showed them the fraction. The students worked in pairs, discussing with their partner to check their bingo cards. On the recording I heard students who had a match enthusiastically say "Yeah! We do" while another group said "No! We don't" expressing disappointment. When I noticed that all students had finished marking their cards I picked a new fraction. All students were looking directly at me and waiting for the next fraction. At this point in the session, it seemed as if they couldn't wait for the next fraction. I announced 2/8, stating "two eighths" and then, all students quickly checked their cards and one of them said "We have it" excitedly. I asked if everyone was ready to move on, and all students confirmed they were. I announced the fraction ½, stating "one half" and students were discussing if this fraction was represented on their card. A student stood up for a better view of his friend's card while another student was trying to understand his friend's work. One student asked; "Is this two thirds?". Then I asked, "What is the meaning of one half?" and one student raised his hand and answered. I confirmed that his answer was correct, and the other student recognized his mistake, saying “oh oh oh”. I asked if everyone was ready for the next fraction. I then asked the students to read the fraction aloud while I held it up it for them to see. The students read it together by saying “three ninths”. They checked their bingo cards, and one student said that “nobody has that fraction” while others were checking their bingo cards. I asked if everyone was ready for the next fraction, meanwhile one student shouted “bingo” and started laughing and saying that he was joking. This process continued as I drew additional fractions.

After a few more fractions were drawn, I asked a student to pick the next fraction. She chose one and handed it to me, and I showed it to the class. They read it aloud as "three and one half." I asked, “what does that mean, three and one half?” One student raised their hand and explained, “It means we have three whole numbers and one-half”. I repeated the explanation to reinforce understanding, then asked if “everybody found it on their bingo cards?” Several students confirmed that they had finished checking. I asked another student to pick a fraction and show it. Then, I showed the fraction to the group and the students read “four eighths”. One of the students asked, "Can I pick now?" I allowed him to pick a fraction while others were watching. The student showed the fraction and read confidently “One quarter.” I repeated to ensure everyone heard it clearly. The students checked their cards for 1/4. I reminded them to check carefully and asked if everyone had found it. They said, “Yes,” eagerly waiting for the next one. The student picked and read it as “three whole and two thirds”. I repeated it. Students were checking on their bingo cards and discussing the fraction with each other.

As this process continued, students called out how many more fractions they needed to fill their card saying things such as, “only two left” or “only three left”. Most also expressed a keen interest in being allowed to draw the next fraction. When one student chose a fraction and read it as ”one half”, I raised my hand, showing it to the class, and reread it as “two and one half”, then clarified, “Two wholes, one half.” The students began checking their bingo cards for that fraction. The students began discussing among themselves, some engaging in a conversation about what they needed to fill their card. When I asked them, “Did you all check?”, the students responded in unison, “Yes!”. When one student picked a fraction and read it as “one and one two”, I corrected him and said “one and one half”. The students excitedly asked if they could take turns picking a card and I explained that we would proceed in a counterclockwise order, with each student taking a turn. After a few more fractions were drawn, one group excitedly shouted, “Bingo!” I explained that we would check their cards. The students read the fractions aloud. However, some seemed distracted and started chatting. After confirming all fractions were correct, the winning group celebrated by raising their hands and shouting “Yay!”. I then announced, “Now it's time to clean up!” and some students reacted, “aaa” and “What?”

Summary of Video of Small-group Play for the Fraction Story Game. In this game, the same group of eight students played the Fraction Story Game immediately after playing Tombamath. However, I paired the students with new partners. Each pair picked one fraction story from the bag and one manipulative to explain their fraction story. Then, they read it and discussed with one another. I said “you have three minutes to work on the question” and reminded them to create a representation using the manipulatives. I moved around the table checking on their representations. Some students finished before the given time and said, “I am done.” I said “let them finish” indicating the other students. Then, I started with one group and asked them to read their question and explain it using the fraction circle manipulative that they had been given. Some of the other students were looking at them and listening. However, other students were looking for their representation or looking at the cameras and making humorous gestures. After the first group finished explaining their response, I confirmed that they were correct and moved to the second group who began to read aloud the question they had worked on. Meanwhile, some students were chatting among themselves and seemed distracted. Noticing this, I gently reminded them, saying, “No, no, we need to be respectful.” After the student explained their representation, I confirmed that it was correct and asked if the other students understood. Some students said that they didn’t understand. I explained what the students had done using 12 unifix cubes. Afterwards, the next group read their question aloud. All students watched and listened. While one student read the question, another explained their representation using the fraction strips.

Meanwhile, a member of the second group gathered the unfix cubes and stacked them on top of each other, combining two bars and counting the total number of cubes. At the same time, their teammate observed the stacked cubes while the student continued explaining their representations. Then, it was the fourth group's turn. First, they read aloud the fraction question. Then, I asked if everything was clear. The student then explained their response, including the representation using the number line, while everyone listened. I confirmed that their explanation was correct and asked if there were any questions. Then, I explained that they would play the game for one more round and I asked the students to switch the manipulatives. Everyone gave their manipulative to the person next to them in a counterclockwise direction. When they changed manipulatives, one of the students complained; “I want blocks.”

After changing the manipulatives, I got the students' attention and explained the rules again. The children were talking among themselves, and their attention seemed to be decreasing. I told them; “We have last five minutes, then we will stop.” Still, they kept talking and I said, “I need your focus here!” but they were still talking. I then said, “Check five.” This is a process their teacher uses to get their attention. They raised their hands and focused on me. Then, each group drew a new question from the bag, and they started to read it. In the first group, only one of the two students seemed interested in the activity while the other did not seem engaged. In the other three groups, both students seemed engaged and participating in the activity. I gave them just over a minute to complete the task. Some groups finished earlier while others were still working. I asked the students who had finished to wait for the others. At this point, another teacher came into the room which attracted the students' attention. One student stood up and tried to see while others talked to each other. I tried to get their attention and said "Excuse me! We are not done yet". When one group asked for my help, other students were talking to each other and seemed distracted. I again asked them to "check five" to get their attention and then invited students to take turns explaining their representations while their classmates listened. I sometimes invited other students to explain how they understood the fractions that other groups had represented. Some of the students were listening while others were engaged in different activities and fidgeting in their seats as though they were bored. One student stood up and asked to leave just as the last group read their question and explained their response. Other students had also become distracted—one stood up and started walking around, while two others crawled under the desk. When the last group finished their explanation, I asked the students, "How do you feel? Did you guys enjoy it?" Although they answered "yes," they appeared to be bored. Then, I said, "it is time to clean up."

Findings Across Data Sources in Relation to Research Questions

In this section, I present the findings of the study in relation to the research questions after considering the four data sources (student questionnaires, teacher interviews, classroom observation, and video recording observations). I highlight key themes that emerged from my analysis of the data.

Research Question 1: What are the students' reported experiences as they engage in game-based learning focused on fractions in relation to design characterises of two games?

The data for this research question come mostly from the questionnaires and video recording observations with a few insights coming from my observations of the full-class gameplay sessions. Five main themes emerged from my analysis: 1) Competition and game-driven motivation, 2) Luck-based game, 3) Collaboration, 4) Level of Challenge, 5) Using manipulatives. In this section, as I discuss each theme I try to focus only on students' reported experiences (what they wrote or said). I return to these themes in later sections to consider the teacher's perspective as well as my perspective as a researcher.

Theme 1: Competition and game-driven motivation. The data gathered from these two games suggests that the competitive nature of the games, particularly Tombamath, played an important role in enhancing these students' motivation to play the games. On the questionnaires, four students selected "Excitement" as one of their feelings while playing the games. Some of the other data suggests that this excitement was often linked to their desire to win. For instance, the video recording observations of the small group showed that these students were excited about being the winner in Tombamath. Students who were close to winning said things such as "One more" or "Two more" excitedly as they got close to filling their Tombamath card. This finding is further supported by my classroom observation notes where I recorded that some students were shouting "We will win" excitedly and others were saying "Only one left to win" while playing Tombamath. Likewise, after a new element was added to the Fraction Story Game, namely writing your own question at the end, I noted that several students said, "I wrote more questions”. This suggests that some students had turned an aspect of this non-competitive game into a competition where they equated writing more questions with winning.

Furthermore, the findings illustrated that students were very disappointed when they lost. Some students reported this frustration in their questionnaire responses. For instance, one student wrote, “Sometimes when I do not win, I feel sad and mad”. Similarly, another wrote “I liked how I would win but I never sadly” to state their frustration with losing. Another participant echoed this focus on winning and losing writing, “There were some sore winners and some sore losers”. The data obtained from video recording observations also support this finding. As an example, when the fraction that was drawn didn’t match their bingo cards in Tombamath, the group expressed their disappointment, stating “No! We don’t have it”’.

The findings also suggest that some students lost their motivation and got bored more easily in the non-competitive Fraction Story Game. The questionnaire data supports this finding. For example, when asked what they disliked about the games, one student noted “get boring fast” in relation to the Fraction Story Game. Moreover, when asked which game they like more in the questionnaire, six students chose Tombamath indicating that they found it more exciting. For instance, one student wrote “Tombamath so it is more exciting”. Similarly, another was stating “Tombamath because the bingo part is more fun” while one participant was expressing “Tombamath is fun game”. My classroom observation notes also support this finding as I noted that after playing the Fraction Story Game, some students stated, “It was boring!”.

Theme 2: Luck-based game. Both the questionnaire data and the classroom observations suggest that some of these students disliked the luck-based nature of Tombamath. Some students expressed their frustration in having to depend on luck in their questionnaire responses. For instance, when asked what they disliked about the games, one student stated “I don't like. It mostly about luck" referring to Tombamath while another reported "Because it is very interesting and unlucky" referring to the Fraction Story Game. Another participant complained about Tombamath depending on luck writing, "Very unlucky and weird". Moreover, another expressed their disappointment at not being the winner due to bad luck, stating "That sometimes unfair". The data obtained from classroom observation notes also support this finding. As an example, when the fraction that was drawn did not match their bingo card, some students were unhappy and called out "Aaaaa! it's not fair." Similarly, when the Tombamath game ended, the losing groups were not pleased with the outcome, expressing their frustration "That's not fair!" or "You didn't give me the lucky card!". In addition, as noted earlier, when the same group won Tombamath during the first two full-class gameplay sessions, some others complained about it saying, "They rigged the game" and "They are cheating". Notably, this theme is partially related to the theme of competition and game-driven motivation, because the reason that some students indicated they did not like games based on luck was that winning depended entirely on luck rather than an element of skill. In Chapter 5, I discuss other aspects of competition and luck in relation to the teachers approach to these aspects of mathematics teaching and in relation to the literature.

Theme 3: Collaboration. Both questionnaires and the video recording observations revealed that many of these students like when games involve teamwork. Some students expressed their enjoyment of teamwork in their questionnaire responses. One child stated "I liked that the game included teamwork" while another student wrote "I like the teamwork" when asked what they liked about the games. Likewise, the video recording observations confirm this finding. In the video, students were actively working and discussing with their partner to check their bingo cards in Tombamath. This aspect of Tombamath would not have been observed if we had given each student their own card when we implemented the game. Collaboration was also visible for the Fraction Story Game both when students were working together to create their representations and when they were sharing their responses where often one group member read the question from the paper while another explained their answer to their classmates.

Theme 4: Level of Challenge. The data gathered suggests that the level of challenge of each game affected these students' attitudes toward the game. The level of challenge for these games seemed to relate to both their familiarity with the gameplay elements and to the mathematics concepts in the game. The questionnaire data suggests that when students are familiar with the game, they feel more confident and comfortable, which in turn increases their motivation to play the game. Some students, for instance, stated in their questionnaire responses that they liked Tombamath more since it was similar to Bingo, writing "Tombamath, because the bingo part is more fun" and "Tombamath because I like bingo because it's fun". On the other hand, some students expressed that the Fraction Story Game was difficult for them, particularly as they were getting used to the gameplay. For example, one student stated, "At the start it was too hard it did get easier because I didn't understand" in their questionnaire response. The classroom observations also support this finding. At the beginning of the Fraction Story Game, students had a hard time understanding what they needed to do, and I noted comments such as "I don't understand, it's so hard!" "I don't know how to do this!" and "It seemed confusing at first, but after a few questions, it became clearer.".

I also want to point out that I believe that the Fraction Story Game invites students to engage more deeply with mathematics than Tombamath. Students need to find a solution and represent that solution using manipulatives. Conversely, in Tombamath, students only need to match each fraction with its representation on the card. Although the representations are varied in format on the game cards, the reasoning required to match a fraction to these representations is likely less demanding than the reasoning required to create representations of fractions that align with the fraction story. This may explain why three students expressed that the Fraction Story Game was difficult for them in the questionnaire. For example, one student expressed his feeling about the Fraction Story Game, saying “it made me too stressed” while another wrote “Fractions are so difficult” Notably, the Fraction Story Game only included proper fractions whereas Tombamath included mixed fractions.

Theme 5: Using manipulatives. The use of manipulatives is a key design feature of the Fraction Story Game whereas in Tombamath the only manipulatives used were the tokens that students used to cover items on their game card. Both my classroom observations and video recording observations revealed that students were actively working with manipulatives when playing the Fraction Story Game. I noticed that having manipulatives as part of the game seemed to make students happy. I also observed that some students have preferences for some manipulatives over others. For instance, I heard some students say “I want the blocks” in the video recorded session while another student said “I want the fraction circles” during one of the full-class gameplay sessions. I also noticed that when the teacher let them choose the manipulatives they wanted, this seemed to make students happy. It seemed as though students wanted to use manipulatives that they were comfortable with and that this may have helped them represent the fractions in the story more easily. On the other hand, their motivation seemed to decrease when they encountered manipulatives that they had difficulty with. For instance, I heard comments such as “I don't want fraction circles”

Research Question 2: What is the teacher’s perspective regarding (a) the design quality and (b) the use of games for teaching and learning mathematics with Grade 4 students?

The findings for this two-part question are drawn principally from my analysis of the teacher's initial and follow-up interviews. I identified three main themes for the design quality of mathematics games from the teacher's perspective: 1) Competition and game-driven motivation, 2) Level of reading difficulty, and 3) Game adaptability. I also identified three main themes for the use of mathematics games with Grade 4 students from the teacher's perspective: 1) Reinforcement, 2) Taking a break from harder staff, 3) Not an effective assessment tool. In this section I explain each theme and provide quotations from the interview as evidence of the theme.

(a) Teacher's perspective regarding design quality of mathematics games

Theme 1: Competition and game-driven motivation. The teacher interview data reveals that this teacher felt that the competitive element of mathematics games plays an important role in boosting students' motivation to play the games. The teacher stated that competitive elements especially when prizes are involved, tend to boost engagement by noting that "The competitive piece definitely they like that and when there's prizes, they're even more competitive" (Follow-up interview, Lines 264-267). Similarly, the teacher highlighted that having a winner at the end of the game also boosts students' motivation and engagement with the game. She also expressed the view that Tombamath, which is more competitive than the Fraction Story Game, had a positive impact, stating "the first game I would say was positive [impact on classroom dynamic] because they were all trying their best to win." (Follow-up interview, Lines 109-110). At the same time, data obtained from the interview reveal that the teacher emphasizes the importance of students doing their best and encourages students to explore their own learning experience, as a way to reduce the competitive environment in the classroom. She expressed that "we're going to say to ourselves, you know what I'm going to do the best I can…… And we say

I'm going to try my best. I have maybe had more practice or less practice, but I am going to try my best." (Initial interview, Lines 66-69).

The teacher highlighted that she encourages students to improve their knowledge, develop their self-confidence and compete with themselves rather than others, stating; "We're only comparing to ourselves. If our neighbor is done, we're, we're ignoring our neighbor. We're not paying attention to our neighbor, we're focusing on ourselves and the next time our goal is to beat our own score" (Initial interview, Lines 71-73). There seem to be some mixed messages in how the teacher views competition, describing it as a positive aspect of Tombamath where she observed that they "were all trying their best to win" (Follow-up interview, line 110) while also describing ways that she encourages them to only compete with themselves during mathematics learning activities.

Another important finding from the interview is that the teacher mentioned that when success or winning is based on luck, students complain and express their frustration. For instance, she recalled that students got frustrated because Tombamath was based on luck, with one stating, "I didn't have a lucky card." (Follow-up interview, Line 117) while another stated "You gave me an unlucky one" (Follow-up interview, Line 117).

Theme 2: Level of reading difficulty. The teacher expressed the view that the level of reading difficulty is an important design quality in games. In both the initial interview and the follow-up interview, she explained that reading comprehension varies among Grade 4 students and that this is a game design feature that may impact their engagement with the game. The teacher noted that "it needs to be simple enough so that the kids can get it easily" (Initial interview, Line 190). She expressed the view that when you have students with different backgrounds, simplicity is essential to ensure all students follow and understand the game, saying “When you have a huge diverse group, if you make the game simple enough that they're all going to catch on quickly” (Initial interview, Lines 193-194).

In the follow-up interview, when discussing the Fraction Story Game, she explained that “they had to read it, they had to make sense of it and often some of the questions had like a second or third part to it. Yeah, it’s maybe too much” (Follow-up interview, Lines 134-139) because “there's quite a few that aren't at grade level for reading” (Follow-up interview, Line 130). Overall, she stated that she thought the Fraction Story Game was more complex for the students because it required more reading than Tombamath.

Theme 3: Game adaptability. Another insight from the teacher interview data is her view that mathematics games should be designed so that they can be adapted when necessary. In the interviews, she explained a number of ways that games might be adapted including being able to make them more or less challenging and being able to use different approaches to grouping students. In the initial interview, she stated “Since students are not at the same level, the game should be suitable to modify when necessary” (Lines 219-220). If students need to be challenged or are ready to progress, they can move to the next level or if the game is difficult for students, it can be modified according to their level. The teacher also stated, “you need to have enough variety within what you're doing so that the kid can be challenged if they need a challenge or they're going to be able to stay at that same level until they're ready to progress” (Initial interview, Lines 203-206). The teacher also felt that student groups formed during the game should have a flexible structure and that it is important to adapt the group structure according to each student's needs. The teacher highlighted her view that the active participation of some students in the game is directly related to the group members, stating “it depends on the group and it's, it's hard because sometimes it seems like they might be more active with a friend, even if that friend is higher than them." (Follow-up interview, Line 34-36) and "At other times, if you put those same kids together, depending on the skill, they don't want to show that they can't do it, and then they want to go with their friend that they know is, you know, maybe as low as they are." (Follow-up interview, Line 40-42).

Notably, during the full-class gameplay sessions, the value the teacher placed on game adaptability as a design feature was evident in her actions. That is, she made a number of adaptations in how the game was facilitated for both Tombamath and the Fraction Story Game. She used flexible groups for both games and when the Fraction Story Game became more familiar to students, the teacher adapted the game to help maintain students' engagement by asking students to write their own questions.

(b) Teacher's perspective on use of games in mathematics teaching and learning

The following three themes emerged in relation to the use of mathematics games with Grade 4 students from this teacher's perspective.

Theme 1: Reinforcement. In the initial interview, the teacher explained that she uses mathematics games as "reinforcement of skills that they [the students] already know" (Line 108) rather than as a way to introduce mathematics concepts. She explained "the game is more for reinforcement. So, I don't usually start anything with a game until they know what the thing is, and then usually the games are more of if you're done your work, you can practice this" (Initial interview, Line 100-102). She emphasized that the use of games in mathematics education can enhance learning stating, "I think like playing the games or any time that they can be involved in an activity and working with somebody and doing something I think is super helpful for their learning" (Follow-up interview, Line 297-299). At the same time, she expressed the view that gameplay is not as effective as other means of practicing mathematics concepts. She expressed this by stating “They can work through things [mathematics concepts] in a game and they can watch the neighbors if they don't understand. But I think sometimes they need to just sit with their work and struggle with it and face that struggle by themselves” (Line 378-380).

Theme 2: Taking break from harder tasks. The teacher explained that playing games in mathematics classes is something she does to give students a break from harder tasks. For example, she mentioned that “we're having kind of a, a down day where the kids just need a break..... I'll just you know, let's have game day” (Initial interview, Lines 114-118) and “they just pick and choose whatever one they want. It’s just a fun thing you know, they’ve done a whole bunch of work and we need some stuff to do” (Initial interview, Line 124-130). She also added, “I probably should be doing games more because kids really do like games” (Line 134). She reiterated this idea in the follow-up interview stating that games provide “a fun break from focused thinking time” (Line 319-321), which students also need, making the learning process more balanced and enjoyable. On several occasions during the interviews, the teacher noted that games are also a means of having fun for students. She supported this with “games make their moods up, especially if they like and enjoy the game.” (Follow-up interview, Line 314-317).

Theme 3: Not useful for assessment. Another perspective which the teacher expressed regarding the use of games in mathematics teaching and learning was her concern that games cannot be used to determine how students are understanding mathematics concepts or as a form of assessment. She stated that “it’s really hard to find the accountability, if you are using games especially as an assessment piece.” (Initial interview, Line 137-138) and she explained this concern, saying “Sometimes it looks like they might be doing what they need to do, but are they really getting the idea of what that game is there to teach them, or are they just sort of moving things around and their neighbor is telling them all the answers?” (Initial interview, Line 142-

145). She also expressed that the games are not like an assessment where you can ask questions and determine the level of students, stating “So, with the test you can see what they're doing. You can mark it. You have’ Okay, good this kid gets it.’ And when they're doing an assignment, you can go around and ask them questions, but with the game, sometimes it's harder to have that accountability piece” (Initial interview, Line 138-141).

Research Question 3: What are the researchers’ observations of a) the design characteristics of each game given the data that was gathered in the study? b) What improvements might be made to each game?

Based on the data gathered in the study, in this section I outline my observations about some of the design characteristics of these games. I categorized my observations using four themes: 1) familiarity and novelty; 2) competition; 3) collaboration; and 4) luck and skill. Moreover, I make some suggestions for improvements for each game based on my observations of the experiences of these students

a) Researchers’ observations of the design characteristics of the games

Theme 1: Familiarity and Novelty. Based on my observations, both familiarity and novelty played important roles in shaping students' engagement and motivation in the game. I noticed that familiarity with game rules and structure in Tombamath provided students with a sense of comfort and confidence, allowing them to focus on applying their knowledge rather than learning new concepts or gameplay rules. For example, the questionnaire data showed that some students indicated that they like Tombamath more since it was similar to Bingo, stating “Tombamath, because the bingo part is more fun”. However, it seemed to me that familiarity can sometimes lead to boredom and reduce students’ engagement in the game. For instance, during full-class gameplay sessions, I observed that students lost interest and showed less participation after playing the same game several times. On the other hand, novelty brings in new elements that capture students' attention and maintain their interest. My observations from the video recording support this. As an example, while playing Tombamath, allowing students to pick their own fraction cards seemed to increase students' motivation to play and their participation in the game. I heard that one student asked; "Can I pick now?". Similarly, I also observed in full-class gameplay sessions, that the teacher brought novelty to re-engage students whose interest may have decreased by adding a new element to the Fraction Story Game which was writing their own questions.

Theme 2: Competition. Among the design characteristics observed, many students reacted positively to competitive elements in the games, which appeared to stimulate both their motivation and their active participation in gameplay. According to my observations from gameplay sessions and the video recording of the small-group session, the main source of this excitement and motivation for the game was the students' desire to be the winner. For instance, although the students' attention was occasionally distracted in Tombamath (the more competitive game of the two), when a new fraction was drawn from the bag, they immediately refocused on the game and checked whether the fraction was on their card. Furthermore, the same group won in the first two gameplay sessions in Tombamath and some of the other students expressed that they wanted to be part of that group in order to increase their chances of winning in the third gameplay session.

On the other hand, I did not observe the same enthusiasm when students played the Fraction Story Game which had no competitive element. Each group of students represented their fraction with manipulatives when it was their turn, and the game ended when they had worked with all the manipulatives rather than when a winner was identified. It seemed to me that when their turn was over, the students in that group felt like the game was over for them and they began to lose interest. I noticed that it was harder to refocus them because there was no winner or reward at the end of the game. When the teacher added a new element to the Fraction Story Game, inviting students to come up with their own question, as noted earlier, some students began to compete in terms of who had created the most questions. During the full-class gameplay sessions, I also heard some students complaining that they found the Fraction Story Game boring. Along similar lines, during the small-group session, I saw that the attention of students was lacking in the Fraction Story Game. For example, one stood up and started walking around, two others crawled under the desk, and others were engaged in fidgeting activities such as rapidly shaking their legs. Although I believe this may have been due to the lack of competition in this game, I am also aware that students played Tombamath first in the small-group gameplay session and the Fraction Story Game second and so they may also have begun to be tired of the structured activity.

Another observation I made was that the students seemed to focus more on the idea of winning rather than understanding the concepts the game was trying to teach. What was important to them was winning rather than the content of the game. This was most evident in Tombamath, as noted in the observations shared earlier, which was the more competitive game.

Theme 3: Collaboration. Collaboration was a key element in the design of both games. In both Tombamath and the Fraction Story Game, I saw that the majority of the students tried to solve questions by discussing with their group members. Another important observation relates to the students' preferences of group members. In the full-class gameplay sessions, I heard many students state that they wanted to be in the same group with their close friends. I could see that students who were close friends sometimes seemed to distract each other from the game.

Although working with a friend seems to increase student motivation for the game, it may also reduce the effectiveness of collaboration on student learning. Another point I observed is that it seemed beneficial to change the groups every gameplay session because students seemed to get bored fairly easily. Changing the group dynamics in both games may be one way to maintain their motivation.

As I mentioned in my summary of my observation notes, I noticed that gender distribution within groups as well as whether or not students could choose their group members, seemed to influence their engagement with the game. When there were more boys in a group, the girls seemed to be less active in the game. Conversely, when there were more girls in a group, the boys seemed to be less active in the game. At the same time, mixed-gender groups in the classroom seemed to show higher interest in both games compared to groups consisting of only boys or only girls.

A closer look at the way that collaboration unfolded for each game suggests that most students primarily focused on being the winner in Tombamath, but the level of active participation varied within each group. For instance, while some students took an active role in finding fractions representations, others tended to wait for their friends to find the solution. On the other hand, in Fraction Story Game, collaboration was more balanced, with most students sharing responsibilities and working together to solve the fraction stories.

Theme 4: Luck and skill. My classroom observations suggest that the students were disappointed with the fact that Tombamath was largely based on luck. They complained about their success being based on more luck rather than skill in all three gameplay sessions of Tombamath. For example, I saw that when a new fraction card was drawn, if the fraction did not match a representation on their bingo cards, some students would react with disappointment by saying, “Aaaa! It’s not fair!”. In addition, I heard others complaining during the game, stating “You didn’t give me the lucky card!”. They seemed disappointed that it was all up to luck and their skill did not affect the outcome. Also, this disappointment seemed tied to their focus on winning. Even though they were very excited throughout the game, they were unhappy that they did not win due to not being lucky. This situation sometimes seemed to negatively affect their motivation. Moreover, the fact that the same group won in two full-class gameplay sessions of Tombamath created discontent among some students. Some students, who felt that the outcome of the game was unfair, claimed that the winning group had cheated. I heard some students who didn’t win shouting “They cheated “or “They got the lucky card” several times during the game.

b) Suggestions for improvements to each game

Tombamath is a bingo-like game in which students draw fractions and match them with the appropriate representations on bingo cards. The first group that covers every fraction on their card wins. This game allows students to both recognize visual representations and reinforces basic fraction concepts in a fun way. However, based on my observations in this study I can suggest some improvements to enhance the game to further develop mathematical skills, reduce the role of luck, and make it more inclusive. Instead of the game proceeding solely as a fraction-representation match, students could be presented with short problem cards. Students randomly select a problem card from this pile, discuss it within the group, solve it, and match their solution with the correct representation on their card. Incorporating such problem-based tasks into the game would allow students to think not only at the level of recognition but also at the level of interpretation and application. However, when preparing such problems, in light of the comments the teacher made about reading levels, I think that care should be taken to ensure that the texts are short and appropriate for the students to read. This approach would allow for a more balanced game between luck and skill.

In addition, instead of simply completing the game first, a more inclusive structure could be used where every group that completes their card wins. This might increase students' motivation and change the sense of competition in students. Such a structure would encourage focus on the learning process and ensure that not only the lucky group is rewarded, but also attentive and collaborative groups. The fact that the game already has a group-based structure provides an opportunity to develop cooperation and communication skills among students. In this context, active participation can be encouraged by dividing tasks among students. For example, one student might read the problem, another find the representation, and another verify the accuracy of the solution. Additionally, prompt conversation cards or reflective questions can be used after the game to increase interaction within the group. These practices might better support students' mathematical thinking and result in deeper collaboration within the group.

The Fraction Story Game is a game in which students draw fraction stories from a bag and represent their solutions by using four different manipulatives. This game allows students to both understand different representations of fractions and develop their reasoning skills. However, I can make some suggestions for improvement to this game design based on the data that I gathered. The stories on the problem cards could be simplified to facilitate student understanding. This simplification might support engagement among students who struggled with reading or mathematical language. Furthermore, instead of just written out questions incorporating video or photo prompts with the questions could provide varying levels of support for students with different needs. Another change that could be made is to determine the manipulatives for each group to use when working on one fraction story by rolling dice. This would bring an element of chance into the game and improve the balance between luck and skill. The original version of the game does not have any luck components in it. In this revised version, each manipulative option would be assigned a number. Students would roll the dice and then have to use the manipulative that matches the number on the dice. This adds an element of randomness to the decision-making process, increasing both excitement and a sense of fairness. It might also lead to rich mathematics discussions about why some fraction stories are easier to represent with certain manipulatives and more difficult to represent with other manipulatives.

Chapter 5: Discussion, Limitations and Significance

Although several themes emerged during my analysis, in this chapter I have chosen to focus on the importance of teachers using their professional judgement as they consider the learners in their classroom and try to find an appropriate balance among several design features of mathematics games. Specifically, I discuss the need to find a balance between competition and collaboration; luck and skill; and familiarity and novelty. I then discuss three aspects of game implementation that teachers should also consider as they design or select games for use in their mathematics classrooms: intended purpose(s), group composition, and adaptability. In each of these discussions, I consider the observations from my study in relation to the literature. I then identify the limitations of the study as well as the significance and contributions the study can make for teachers who are planning to design or use games in their mathematics classrooms. I also suggest some of the ways that this study may contribute to the literature on the use of games in elementary mathematics classrooms. Finally, I suggest a few areas for further study which became apparent to me after gathering and analysing the data from this study.

Balancing Competition and Collaboration

The findings suggest that the competitive nature of games may play a significant role in enhancing students' motivation to play a game. In my study, the classroom observations suggested that these students were excited by the desire to win, and this increased their motivation to play, particularly for Tombamath. Sundari and Hertuti (2022) found in their study that competition in games increases fourth grade students' involvement in learning activities. Fish et al. (2023) also revealed that competitive conditions can increase 1^{st} and 2^{nd} grade students' motivation and focus on the task. However, they observed that especially 7–8-year-old boys pay less attention to mathematics tasks (proportional reasoning) in a competitive environment and that competition does not provide equal benefits for all students. On the other hand, the same study found that collaborative learning environments support students' commitment to their tasks and positive attitudes. In this context, it is important to establish a balance between competition and collaboration considering the needs of students during the game design process.

Furthermore, it is also important to note that even though some students may enjoy competition, it does not always lead to positive results. In fact, some students in my study stated that they felt sad and disappointed when they could not win during the game. Ryan and Deci (2000), in their work on motivation, stated that those who win may find competition motivating but for those who lose it may be discouraging. They also discuss the relative value of intrinsic motivation over extrinsic motivation. Winning, which is one aspect of competition, is probably most often a form of extrinsic motivation. I did notice in my observations that one student found the competitive nature of the games particularly upsetting writing on the questionnaire that "Sometimes when I do not win I feel sad and mad." I also heard expressions of disappointment from students when their group did not win. These varied experiences with competition highlight that the range of student's emotional reactions should be taken into account when designing and implementing game-based learning. Since the reactions of students to winning and losing situations, especially at the elementary school level, may affect the gains they receive from the game experience, I think that during the game design process, the teacher must use their professional judgement to balance elements such as collaboration and common achievement goals with competition along with the needs of the students in their classroom. In Tombamath, the balance was more toward competition whereas in the Fraction Story Game, the balance was more toward collaboration.

One factor that may be important when deciding the degree of competition in games that teachers create or use with a group of students may be to consider the approach to competition the teacher is using in other aspects of their mathematics pedagogy. For instance, the teacher in this classroom described how she encourages students to compete with themselves rather than with one another when completing mathematics tasks (i.e. she tells them “Some of us haven't had more practice, so we're going to say to ourselves, you know what I'm going to do the best I can, and often I'll have them point to themselves…..And we say I'm going to try my best.” (Lines 66-69). And yet, the students did not seem to demonstrate this perspective when playing these two games. That is, many students spoke and acted in ways that suggest that they were actively competing with one another. If a teacher is trying to reduce the emphasis on competition in their mathematics classroom, it may be important to design or select games to use where there is less emphasis on competition and greater focus on collaboration.

Balancing Luck and Skill

The findings of this study suggest that many students dislike luck-based games. In their questionnaire responses, five of the 12 students who responded expressed their frustrations with the fact that winning in Tombamath depends on luck. In particular, the student’s motivation was impacted because their success was determined by luck rather than individual effort. In contrast, luck was not a significant factor in the Fraction Story Game. In Parsons (2008), the author describes three game categories related to luck: luck, a mixture of luck and skill, and pure skill. He suggests that luck games don’t hold students’ attention for long since they cannot control the outcome. A similar observation was made by Russo et al. (2018) who presented five principals of educationally rich games. They suggest that mathematics games must strike a balance between skill and luck to ensure students' attention and motivation to participate. Similarly, Parsons

(2008) indicated that a good balance includes enough skill to challenge everyone but enough luck to give each student a chance to win. My classroom observations support this finding. As students lost one game after another when playing the luck-based Tombamath, I saw that although they were very excited throughout much of the game, their motivation seemed to gradually decrease, and they were disappointed at the end.

The observations related to luck in my study suggest that students may expect their effort to have a greater impact on the outcome of the game. This might relate to self-efficacy theory which states that individuals with high self-efficacy are more likely to engage in a particular subject or task, tend to approach that topic or task with confidence, put in more effort, and persist in overcoming challenges because they believe they can succeed through their own efforts (i.e., rather than due to luck). It seems likely that students with low self-efficacy might respond differently to luck than whose with high self-efficacy. Another possible explanation for this might intersect with many students' desires to win. Therefore, it seems possible that students dislike of luck-based games might be linked to their feelings of self-efficacy and their experiences of success or failure in competitive games.

Of course, luck is typically much more relevant in games that are competitive than in games that are cooperative. A cooperative game may have elements of luck in it but perhaps students would not be as concerned with luck in that context because ultimately, instead of focusing on winning or individual victory, their main focus may be on teamwork, collaboration, working toward a shared goal and developing strategies together. The suggested modification for the Fraction Game Story that involves determining which manipulative a group uses when working on the next problem by rolling dice is a way of introducing a luck element without a focus on competition or winning the game.

Balancing Familiarity and Novelty

My observations suggest that familiarity in a game may affect students' attitudes toward the game and their motivation to play. Many students stated that they liked Tombamath more than the Fraction Story Game because it was similar to bingo, a game design that their teacher mentioned she had used for other mathematics learning activities. Notably, Tombamath included more complex fractions than the Fraction Story Game, but students expressed that the Fraction Story Game was difficult for them particularly before they had a sense of the game structure.

Likewise, in their study, Jaaska et al. (2022) conducted a quasi-experimental study with students at six European higher education institutions to analyze their GBL experiences. Jasaka et al. noted that many students expressed that since they were not familiar enough with the game, they made mistakes, and that created disappointment and negative feelings in them. Similarly, Gareau et al. (2009) found that graduate students in the U.S. tended to choose the game that they were familiar with. Although much older students were the participants in these studies, the observations in my study similarly highlight the importance of sometimes using familiar games with elementary students. In addition, when introducing a new game, it is important to ensure that students are familiar with the rules and game structure. Teachers should use their professional judgement and knowledge of their students as they carefully consider these dimensions of familiarity in order to help shift students' attitudes toward a mathematics game in a positive way and increase their motivation to play.

However, the findings from my observations also revealed that sometimes too much familiarity can lead to boredom and reduce students' engagement in the game. For example, I observed in full-class gameplay sessions that students lost interest and showed less participation after playing the same game several times. On the other hand, in my study, I found that novelty brings in new elements that can capture students' attention, maintain their interest and increase their motivation. For instance, as noted, after a new element was added to the less competitive Fraction Story Game, namely writing your own questions rather than selecting a question to read and work with, students' motivation seemed to increase, and some students made competitive statements such as "I wrote more questions!". However, this change in gameplay only took place on one occasion and students' increased attention when this was introduced may have been partly due to novelty. According to Ryan and Deci (2000), motivation can be categorized as intrinsic and extrinsic. Intrinsic motivation, in particular, is linked to the tendency to seek novelty and challenge. Therefore, integrating novel features into games can enhance students' intrinsic motivation. In this context, it is important for teachers to consider students' needs and establish a balance between familiarity and novelty when designing and implementing games.

Familiarity and novelty in game design can also be related to Vygotsky's concept of the zone of proximal development (Vygotsky, 1978). That is, well-designed games gradually introduce more complex tasks that build on students' existing knowledge, aligning with the idea that meaningful learning occurs in the gap between what a learner can achieve independently and what they can do with guidance from a more knowledgeable peer. In game-based mathematics learning, it is probably a good idea for teachers to design or select games where both familiarity and novelty associated with gameplay and associated with mathematical thinking are situated in students' zone of proximal development, to the extent that this is known to the teacher.

Factors to Consider when Implementing Mathematics Games

The findings of this study reveal several factors that teachers should probably consider as they are implementing mathematics games. In this section, I describe three of these factors which emerged from my analysis of the date: intended purpose(s) of the game, group composition, and adaptability. Teachers would need to use their professional judgement and consider the needs of the learners in their classroom as they decide how to implement these aspects of gameplay.

Intended Purpose(s) of the Game

The findings of this study show that one aspect of implementing mathematics games is the intended purpose for using the game. The data gathered revealed that this teacher uses games as reinforcement of existing knowledge in mathematics learning. The teacher felt that games can be beneficial in practicing existing skills and encouraging active engagement in the learning process as well as fostering meaningful peer interaction. The interview data also shows that this teacher was not using games to introduce concepts, only as reinforcement for concepts that have already been introduced to students. These findings are both consistent and partially contradictory with the study conducted by Russo et al. (2018). While they also indicated the use of mathematics games as an effective form of practice and of reinforcing existing knowledge, they also noted that new knowledge and skills can be introduced to students through games. Similarly, Gareau et al. (2009) noted that games can be used to teach new concepts and to review or practice previously taught topics. These different potential uses of games highlight the importance of purposeful game design for learning mathematics. That is, games might be specifically designed with particular features if they are to be used to introduce a concept. This approach to game design might help teachers feel more comfortable using games to introduce a concept rather than only for reinforcement.

The findings regarding this teacher's perspective shows that another use of mathematics games is to take a break from harder mathematics tasks. The teacher in my study indicated that after a long day, when students need a break, she sometimes gives them time to play games to get away from more challenging activities. She also highlighted that students associated playing games with having fun. A possible explanation for using games for taking a break from more difficult tasks might be to boost students' mood and motivation in mathematics class and increase their enjoyment of learning mathematics through playing games. In their study, Su (2016) indicated that when learning is enjoyable, students are more likely to engage willingly in mathematics related tasks as well as improve their mathematics attitudes. Similarly, Ryan and Deci (2000) also stated in their study that since games are often fun, challenging, and engaging, they have the potential to enhance students' motivation.

Group Composition during Game Implementation

In this study, I found that group composition is another aspect of game implementation that teachers should consider as they design or select games for use in their mathematics classrooms. Students in my study expressed preferences for who they worked with typically wanting to be in the same group as their friends. It seems likely to me that these students felt more comfortable with their friends when expressing their ideas. It may also be the case that working collaboratively with friends on mathematics games can reduce students' feelings of anxiety. According to their study, Ke and Grabowski (2006) investigated the effects of gameplaying on mathematics performance and attitudes of 125 Grade 5 students in Pennsylvania. They concluded that collaborative work facilitates peer interaction and fosters a sense of camaraderie, which can effectively mitigate feelings of isolation and anxiety. At the same time, my observations suggest that group composition may have both positive and negative implications for the collaborative learning process. In some cases, being in a group with friends seemed to improve peer interaction, while in other cases, it seemed to be a source of distraction and a lack of focus on the task. For these reasons, it seems like it might be a good idea to design games in ways that allow students to be in various group compositions - whether the groups are chosen by the teacher or by the students.

Adapting Games During Implementation

My study highlights that adaptability is another consideration for teachers when they are implementing games into their mathematics classrooms. The findings related to the teacher's perspective regarding the design quality of mathematics games suggest that games should be flexible enough to adapt in many ways when necessary. These findings suggest that games should be suitable to modify when students need to be challenged or when they need less a challenging activity. Given the diversity of students in most elementary mathematics classrooms, and the challenges of being aware of each student's zone of proximal development, it is key to be able to adapt a game to the learners based on a teacher's knowledge of the students in their classroom. Similarly, Russo et al. (2018) suggested that mathematics games should be flexible enough to be differentiated for diverse students' groups and adaptable to different mathematics concepts. This design feature helps to maximize students' learning opportunities and can provide a comfortable learning environment for each student. Likewise, Buchheister et al. (2017) indicated that well-designed mathematics games should be adaptable, with different entry points that provide opportunities for critical thinking for all students.

Tombamath is an adaptable game because it can be customized to different skill levels. Teachers can also adjust the difficulty of the fractions and the bingo cards to suit diverse groups of students. It is suitable to play individually or in groups and the teacher can adjust the game and use it to reinforce various mathematics concepts. The Fraction Story Game is also adaptable in many ways. For instance, the game can be adapted by adjusting the difficulty level of the mathematics problems from simple to more complex questions. Teachers can also customize how the game is played, whether individually, in small groups, or as a whole class. Moreover, this game can be played using different manipulatives and used to introduce or reinforce various mathematics concepts.

Limitations of the Study

While this study provides valuable insights into game-based learning, game design and ways of using games in an elementary mathematics classroom, I want to identify several limitations of the research design and observations. One limitation of this study was that the questionnaires provided limited insights into these students' experiences. Most students provided brief answers that did not seem to fully capture their feelings, perceptions, and experiences. They may have been struggling to express their thoughts in writing or did not recall how they felt about each game in very much detail when they completed the questionnaire. Some students may also have felt that they needed to write the kinds of comments their teacher would like to read. I also found that since I was sitting at the back as an observer during the full-class gameplay sessions, it was sometimes difficult to hear what students were saying especially when more than one student spoke at the same time. Additionally, although I used two cameras from different angles during the small-group session, I found that the cameras could not capture all the details. In particular, there were limitations in recording students' gestures and facial expressions, individual reactions and some of what they were saying, particularly if they spoke softly. Some changes to the research design would have made it easier to gather insights into students' experiences with each game.

A study conducted with a larger group of students could have provided more insights as well. I only had consent and assent for 13 students but if I had more student participants, I might have learned more about things such as whether students with less experience with game-based learning might react differently from those who are more familiar with game-based learning. Moreover, I might have captured a wider range of opinions, experience or behaviours related to the two games in the study. This could help me identify themes that did not emerge with this small group of participants.

Another limitation was the time constraint. The study was designed to be completed in a short period of time which poses some restrictions on the depth of data collection for gameplay sessions. Since gameplay sessions were conducted in close proximity to each other, students may have been more easily bored by the games (i.e., since they had played the same game just a day or two before). This may have caused some students to lose motivation to play the games more quickly than they would have if the gameplay sessions were a week apart, for instance. In a more longitudinal study, spreading the game sessions over a longer period of time might lead students to students having a refreshed mindset for each gameplay sessions, providing a better opportunity to observe the effects of each game. This approach might also make it easier to determine if the experiences with gameplay were having an impact on students' attitudes toward mathematics learning.

Another limitation of this study relates to my limited familiarity with the Manitoba educational context. At times, I found that my limited familiarity with the curriculum standards and the ways that it can be enacted in Manitoba classrooms made it difficult for me to fully understand the purposes behind the decisions the teacher made as she facilitated the gameplay sessions Moreover, I think that this may have affected my ability to interpret some classroom interactions in relation to the targeted learning objectives or to the pedagogical approaches the teacher typically used in her classroom.

Ultimately, I learned more in this study about factors that motivate students to engage with or play a mathematics game. However, it is not clear how much this relates to or impacts their attitudes toward mathematics learning more generally. That is, although students engaged in the games, it is unclear whether this experience changed their attitudes toward mathematics in the long term. It is also unclear whether the motivation experienced during the games was due to the nature of the games (e.g. competitive, using manipulatives etc.) or to a more genuine interest in learning mathematical content.

Significance and Contributions of the Study

This study contributes to the literature on game design and use in mathematics classrooms as well as ideas for teachers to consider when implementing games. The findings provide valuable insights about game design features that may foster positive mathematics experiences for students and help teachers who wish to integrate game-based learning into their mathematics classrooms. This research highlights the complex balance between competition and collaboration in game design as one way to boost students' motivation to play a game. Additionally, these findings shed light on the need to balance luck and skill within a game to support student engagement and develop positive attitudes towards the gameplay and hopefully toward mathematics learning. Moreover, the experiences of this teacher and her students suggest that games can serve as a powerful pedagogical tool if they are flexible and adaptable. When designing mathematical games, designing games similar to games that students are already familiar with can help them develop more comfortable and positive attitudes toward the game. When using a game that is less familiar to students, it is important to support their learning of the game rules and structure. Another suggestion is that grouping students during the game can support the learning process; however, more information is needed to understand how the composition of groups can best support learning. Also, to help to ensure that a game is an effective learning tool for diverse students, it may be helpful to have games that can be modified in many different ways, so that students can be challenged when they are ready for a challenge or stay at that same level until they're ready to progress.

The insights I learned about game design will be helpful for me as I design games for use in my classroom in the future. They may also be helpful for other teachers who want to design and integrate games into their classrooms. The insights I learned about how teachers use games in their classroom may encourage educators to reconsider how they use games in their mathematics pedagogy. For instance, teachers can use games not only to reinforce what students have learned, but also as a break from harder tasks and even as a way to introduce new concepts.

Recommendations for Future Research

One methodological suggestion for future studies would be to collect data with elementary grade students using individual student interviews or small focus groups with no more than three students at a time. This approach would likely allow the researcher to gain a deeper understanding of students' experiences, thoughts, and perspectives, as compared with using questionnaires. Some things about students' perspectives that I would be interested to learn more about using those approaches are the impact of luck in cooperative games and in competitive games on students' motivation in games, the way they strategize as they play a mathematics game, and their attitudes toward the game.

In addition, adopting a longitudinal research design with greater intervals between gameplay sessions may help to obtain greater insights into students experience and thoughts with the games they played. This might also provide insights about students who are not equally attentive across games. That is, in this study, I observed that students who were more attentive in

Tombamath were also more attentive in the Fraction Story Game. For these students, it seemed as though the game design features did not make a difference, they were attentive regardless of the nature of the activity. Research that helps to identify game design features that help students who are less attentive in mathematics class become more attentive would be very worthwhile. It is also possible that some students' attitudes and attention levels towards games may change over time. If I were to design a longitudinal study which used a wider variety of games, then I might find individual students whose degree of attentiveness varied from game to game. I could then ask them about the factors that affect their attention while playing each game, the role of the game mechanics or content on their motivation and the impact of various games on their attitude towards mathematics. In this way, the reasons for varying attention levels across games could be better understood and the effect of game design on learning could be revealed more comprehensively.

With regard to ways of using mathematics games in elementary classrooms, it would be interesting to learn more about teachers views of and experiences with introducing new mathematical concepts through games. This use for mathematics games is suggested by Gareau et al. (2009). I would also be interested in studying how games might be used as a tool for formative assessment.

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Appendix A: Overview of Each Game

Game 1: Tombamath (Bingo)

Tombala, known internationally as 'bingo', is a game widely played among family members in my home country Turkiye, especially on New Year's Eve. Using the foundational structure of this traditional game, I designed an educational game called "Tombamath" by integrating mathematical concepts. In Tombamath, the classroom is divided into four groups, and each group is given bingo cards with various fractional representations. During the game, fractions are drawn randomly from a bag, and groups attempt to match these fractions with the ones on their cards. The first group to correctly match all the fractions on their card wins the game. This game has been designed both to reinforce mathematical skills and to introduce students to the concept of fractions in an enjoyable manner.

Objective: The goal is to enhance understanding of part-whole relations in fractions by recognizing and matching different representations of fractions.

Materials:

- A deck of fraction cards, each card showing a specific fraction (e.g., 1/2, 3/4, 2/3, etc.).
- Bingo cards, each displaying various representations of fractions (like pie charts, sets of objects, etc.).
- Objects (e.g. chips or counters) for students to use as markers on their Bingo cards.

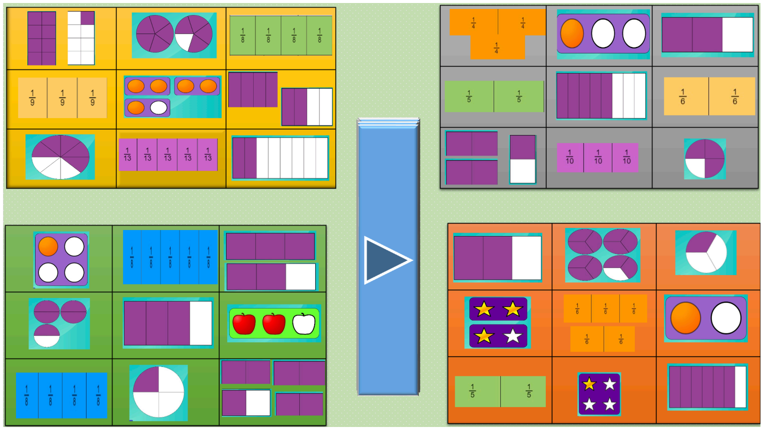
Setup:

- Shuffle the deck of fraction cards and place them in a bag or container.
- Distribute one Bingo card to each group of students.

How to Play:

- The class is divided into four groups.
- Each group is given bingo cards
- The teacher picks a fraction card from the bag and announces it to the class.
- Groups examine their Bingo cards to identify any representation that matches the announced fraction.
- If they find a match, they place a marker on that representation.
- The first group to cover all the representations on their Bingo card shouts "Bingo!" and is the winner of that round.
- The game can be played multiple rounds with different or reshuffled fraction cards.

Example Representations on Bingo Cards:



Guidelines for Reflection

After each round, guide the students to reflect on:

- The fractions they encountered most frequently.
- Different representations of the same fraction and how they recognized them.
- Simplifying fractions and identifying equivalent fractions.
- Peer-feedback
- Reflection and evaluation of their performance and problem-solving strategies.

Game 2: Fraction Story Game

Transporting students into a world of part-whole relationships, this game is designed to turn abstract concepts into concrete experiences. In the Fraction Story game, students will be divided into four groups, and each group will pick one card from the deck to explore real-world fraction scenarios. Each group will be provided with different manipulatives such as counters, fraction circles, etc. After selecting a card, students will represent the fraction scenario using the designated tool and initiate a comprehensive dialogue regarding the part-whole relationship demonstrated. Groups will change manipulatives each round. The game will end once every group has used each of the manipulatives.

Objective: The goal is to understand and explain the part-whole relationship of fractions through real-world scenarios and concrete manipulatives.

Materials:

- A deck of cards, each with a unique fraction scenario.
- Objects (counters, fraction circles, fraction tiles or Cuisenaire rods etc.) that can be used by students to visually represent the fractions.

Setup:

- Shuffle the deck of scenario cards.
- Divide students into four groups

- Assign a specific manipulative to each group to start with.

How to Play:

- The classroom will be divided into four groups.
- A group of students picks a card from the deck.
- They read the scenario out loud and then use the provided objects to demonstrate the fraction situation described.
- The student or group explains the part-whole relationship showcased in their demonstration.
- Other students can ask questions or offer alternative ways to represent the scenario.
- After a set number of rounds (e.g., 3 rounds), groups rotate their manipulatives. Ensure that by the end of the game, each group has used all four manipulatives.
- The game continues until all groups have used each of the manipulatives. Once every group has used each of the manipulatives, the game ends.

Example Scenario Cards:

- "You have a pizza cut into 8 equal slices. You and your friend eat 5 of them. How many slices are left? Represent this scenario and explain the part-whole relationship."
- "You are dividing 10 chocolate bars among four friends so that everyone gets an equal amount. How much does each friend get? Show this scenario."
- "At a birthday party, there's a jug of lemonade that's enough for 6 glasses. If half of it has been poured out into glasses, how many glasses of lemonade have been served? Demonstrate this situation."
- "You have a basket of 12 apples. 1/3 of them are red, and the rest are green. How many of each colour do you have? Represent this fraction situation."

Guidelines for Reflection:

After demonstrating a scenario, guide the students to reflect on:

- The total number of parts (the whole).
- The fraction of parts used or highlighted in the scenario.
- How the scenario might change with different fractions.
- Their experience using the manipulative for that round and how it differed from previous ones.
- Peer-feedback
- Reflection and evaluation of their performance and problem-solving strategies.

Appendix B: Teacher Interview Questions

Initial Interview Questions (prior to gameplay sessions)

1. Can you please provide an overview of your experience with integrating games into the classroom environment?
2. What do you perceive as the potential benefits of using games as a teaching tool in your classroom?
3. Are there any specific challenges or concerns you anticipate in implementing these games in your classroom?
4. How do you plan to introduce these games to your students? Do you have any strategies in mind for maximizing student engagement and participation?
5. In your opinion, how might students typically respond to these games? Are there any potential obstacles or areas where you anticipate they might encounter difficulty?
6. Can you provide any insights or recommendations based on your past experiences or observations that could inform the successful integration of these games into our classroom environment?

Follow-up Interview Questions (after gameplay sessions)

1. Can you describe your overall impression of the students during the gameplay sessions?
2. In your experience, did the gameplay sessions seem to have an impact on classroom dynamics, positively or negatively?
3. Did you observe any noticeable differences in student behaviour or engagement between the two games?
4. Were there specific features of one game that seemed to engage students more than the other?
5. Did you notice any changes in students' attitudes towards mathematics lessons or activities?
6. Do you believe that the gameplay had an impact on students' mathematics anxiety? If so, can you provide specific examples or observations?
7. From your perspective, do you believe integrating such games into the curriculum can benefit student learning? Why or why not?
8. How do you think the game-based learning experience compares to traditional teaching methods, in terms of student engagement, attitudes, and anxiety levels

Appendix C: Student Questionnaire

Name ________________________________

1. What did you like about this game?

2. What did you not like about this game?

3. Were there moments in the game that made you feel anxious or stressed? If yes, can you specify what triggered these feelings?

   - ☐ Frustration
   - ☐ Confusion
   - ☐ Excitement
   - ☐ Engagement
   - ☐ Joy
   - ☐ Boredom
   - ☐ Curiosity
   - ☐ Confidence
   - ☐ Other (please specify): ………………...

4. After playing the game, have your feelings or attitudes toward mathematics changed in any way? Please explain.

5. Which game do you like more: Tombamath or Fractions Story? Why? (This question was asked on the second questionnaire only).

6. Additional Comments:

Appendix D: Approval Certificate

University of Manitoba | Research Ethics and Compliance

Human Research Ethics - Fort Garry
66 Chancellors Circle
Winnipeg, MB R3T 2N2
humanethics@umanitoba.ca

PROTOCOL APPROVAL

Effective: September 11, 2024 Expiry: September 10, 2025

Principal Investigator:	Busra Sahin Celik
Advisor(s):	Martha Koch
Protocol Number:	HE2024-0215
Protocol Title:	*Exploring the Impact of Game Design on Mathematics Anxiety and Attitudes in Elementary Grades*

Liz Millward, Chair, REB2

Research Ethics Board 2 has reviewed and approved the above research. The Office of Human Research Ethics (OHRE) is constituted and operates in accordance with the current *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans- TCPS 2 (2022).*

Please note the following important information about your protocol approval:

i. Approval is granted for the research and purposes described in the protocol only.

ii. Any changes to the protocol or research materials must be approved by the OHRE **before implementation**.

iii. Any **deviations** to the research or **adverse events** must be reported to the OHRE immediately through an **REB Event**.

iv. This approval is valid **for one year only.** A Renewal Request must be submitted and approved prior to the above expiry date.

v. A **Protocol Closure** must be submitted to the OHRE when the research is complete or if the research is terminated.

vi. The University of Manitoba may request to audit your research documentation to confirm compliance with this approved protocol, and with the UM *Ethics of Research Involving Humans* policies and procedures.