The developmental influence of collaborative games in the Grade 6 mathematics classroom

by

Angelique van Coller

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DECLARATION OF ORIGINALITY

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

Department:	Science, Mathematics and Technology Education
Supervisor:	Dr Sonja van Putten
Student name and number:	Angelique van Coller (10318683)
Contact number:	076 225 6550
E-mail:	angeliquevc@gmail.com
Assignment number:	Dissertation
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ABSTRACT

This study investigated the developmental influence of collaborative games in the Grade 6 mathematics classroom. Development in areas such as awareness of mathematics, confidence, competence, curiosity, love for mathematics, appreciation of mathematics, creativity, recognition of mathematics, understanding, and knowledge and skills was investigated. The following three data collection methods were used: intervention, observations, and interviews. For the intervention, a quasi-experimental design was used to assign two out of four classes to an experimental group, and the other two to a comparison group. Fifty-one Grade 6 learners participated in the intervention, which covered the following four mathematics topics: multiplication, nets of 3D-objects, symmetry, and division. Each topic included a pre-test and post-test, with learners being observed during the completion of the post-tests. For the post-tests, the comparison group completed the textbook activities individually as they usually would. The experimental group completed the same activities, but in a game-based worksheet format while collaborating in heterogeneous pairs.

The results revealed that the experimental group increased 4.28% more from the pre-tests to the post-tests than the comparison group. This implies that there was a developmental difference, which can be ascribed to the implementation of collaborative game-based worksheets. The Game Object Model, which was the framework used in this study, provided essential information regarding designing educational games that are conducive to learners' mathematical development. The experimental group increased the most in multiplication and division, which required skills in routine procedures. Low-achieving learners benefited the most from collaborating in heterogeneous pairs in their achievement in mathematics. The experimental group showed a high level of collaboration as they helped each other frequently. A need for support was noted in the comparison group when they asked for assistance from the teacher or a group leader according to the classroom seating arrangements, even though they were instructed to complete the activity individually. Although collaborative games have positively influenced learners' development in mathematics, observations also show that the teacher plays an important role in learners' development in mathematics with regard to focus, motivation, and stirring up a love for mathematics in the learners.

Key terms: Mathematics classrooms; Game-based worksheets; Collaboration; Development.

EDITING CERTIFICATE

Exclamation Translations

To whom it may concern

The dissertation titled, "The developmental influence of collaborative games in the Grade 6 mathematics classroom" has been edited and proofread as of 08 September 2017.

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Melissa Labuschagne trading as Exclamation Translations
http://www.exclamationtranslations.co.za
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LIST OF ABBREVIATIONS

AMESA	Association for Mathematics Education of South Africa
ANA	Annual National Assessment
CAPS	Curriculum and Assessment Policy Statement
GOM	Game Object Model
N/A	Not Applicable
TIMSS	Trends in International Mathematics and Science Study
ZPD	Zone of Proximal Development

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CHAPTER 1 INTRODUCTION AND CONTEXTUALISATION

1.1 INTRODUCTION

Mathematics is an essential part of life because it plays a role in our everyday lives and professions, for example, in business, economics, architecture, engineering, and the medical field, to name a few. Mathematics is either a positive or negative part of learners' lives, depending on how they perceive it. There are ways in which mathematics can be made interesting and fun, which could help develop a positive attitude towards it. Learners explore through play even though they have different learning styles, varying interests, and different levels of ability (Kurtz, 2014). Activities that are enjoyable support learner development by giving learners courage and confidence in their abilities to complete a task successfully (Kurtz, 2014). Learners' mathematical readiness, mathematical conceptions, and interests differ, however, this could be addressed through incorporating differentiated educational games (Trinter, Brighton & Moon, 2015). Moreover, it is more effective to use educational games in a collaborative learning environment (Trinter et al., 2015) as it could promote learner development in mathematics, which could further lead to higher achievement in mathematics.

This chapter presents the background, rationale, problem statement, and purpose of this study, as well as the clarification of concepts, the research questions, and introducing the reader to a short literature review (expanded on in Chapter 2). Furthermore, the theoretical framework (discussed in detail in the second chapter) is also discussed. The present chapter contains a short description of the research methodology, which is further explained in Chapter 3.

1.2 BACKGROUND

The Grade 6 mathematics classroom includes routine, working individually from a textbook, active learning with the teacher, and group leaders providing additional support. Learners are diverse in their development levels and abilities, including low-achieving learners, average achieving learners, and high-achieving learners. Although group leaders are appointed as support for struggling learners, there is a need for collaboration. Routine in the classroom can be varied with enjoyable and fun activities that can support learners' development in mathematics. Development in learners' curiosity, awareness, love for and appreciation of mathematics, creativity, and recognition is linked to positive feelings and attitudes towards mathematics, which can be achieved through enjoyment and fun. According to the Trends in International Mathematics and Science Study (TIMSS) results, learners' enjoyment of mathematics decreases as they get older (Mullis, Martin & Loveless, 2016). Enjoyment and fun can motivate learners to become interested in mathematics and support further development in this subject, as mentioned above.

1.3 RATIONALE

When learners complete a game-based activity, it not only consists of learning content, but also makes mathematics more enjoyable, increases motivation, and makes the content interesting to learners (Ramani, Siegler & Hitti, 2012). This study focused on learners' development in mathematics, which it hypothesises can be achieved through the positive influences of games. Such game-based activities could include crosswords, hidden codes, 'Bingo', or competition between groups of learners (for example, two boys versus two girls). In a study comparing individual learning with collaborative and competitive modes of learning, it was found that when learners worked in small groups, they dealt better with complex information and problem solving (Plass et al., 2013). By making use of games, learners learn through their experience by living and doing, which helps them to become more aware and aids learning (Mayesky, 2009). Therefore, collaborative game-based learning was explored in this study. It was hypothesised in this study that when learning is enjoyable, learners will stay engaged and give it all of their attention, especially when they need the content being taught to be able to participate in a game.

In addition to positive feelings and attitudes towards mathematics, development in understanding and skills are supported through collaboration. Collaborative learning promotes achievement and positive attitudes in learners due to an increase in understanding and problem-solving skills (Capar & Tarim, 2015). According to Ertmer and Newby (2013), learning takes place through practice and through learners' different experiences. Therefore, it is also hypothesised that collaborative games could potentially influence learners' development in mathematics.

1.4 Problem statement

TIMSS is a series of international assessments carried out on 4^{th} and 8th graders, which has been repeated every four years from 1995 to 2015, including a roster of participating countries from all over the world that changes from year to year (Mullis et al., 2016). The TIMSS scales used to measure both 4th and 8th graders ranges from 0-1000, where the participating countries' students' performance typically ranges between 300 and 700 (Mullis, Martin, Foy & Arora, 2012). According to the results from the latest TIMSS, the 4th graders' average for mathematics increased from 515 (1995) to 542 (2015), while 8th graders' average increased from 498 (1995) to 502 (2015) (Mullis et al., 2016). Although the averages increased for both grades, the percentage of 8th graders who disliked mathematics was more or less double than the percentage of 4th graders (Mullis et al. 2016). Between the years 1995 and 2015, 4th graders varied between 15% to 22%, whereas 8th graders ranged from 29% to 34% in their dislike of mathematics (Mullis et al., 2016). Thus, the problem exists that the older learners get, the less they enjoy mathematics even though they continue to achieve success in this subject (Mullis et al., 2016).

Apart from an increase in learners' dislike of mathematics, other common problems include memorising basic number facts, a weakness in computational and arithmetic skills, confusion about terminology and symbols, and failure to understand concepts (Katmada, Mavridis & Tsiatsos, 2014). Learners do most of their learning and activities individually, which could be difficult for struggling learners. Discovery, comprehension, and problem solving is promoted through the incorporation of collaborative learning (Du Plessis, Conley & Du Plessis, 2007). Mathematics is a subject that involves not only facts, but also understanding (Dockett & Perry, 2010), thus developing a deep understanding and acquiring different skills are necessary for learners to support their achievement in mathematics.

Learners enter primary school with differences in readiness, conceptions, interests, and learning profiles (Trinter et al., 2015). An increase in class diversity could imply the need for differentiated instruction, which can be achieved by teachers using different teaching and learning methods (Robinson, Maldonado & Whaley, 2014). When thought and creativity go into game design, and it is well executed, it could provide the context for differentiating instruction, which could meet the learners' different needs (Trinter et al., 2015). Thus, appropriately designed games could increase learners' mathematical development (Hunting, 2010). It is therefore necessary for teachers to explore different teaching styles and to apply these according to learners' different learning needs. One of these methods could involve using collaborative games where learners can share thoughts, ideas, and make joint decisions. A change in education towards more active discovery, learning, collaboration, and fun activities could contribute to learners' development in mathematics with possible increases in achievement in mathematics as a result thereof.

1.5 PURPOSE OF THE STUDY

"A penny spent on learning may be worth a dollar in development" is a quote that paraphrases Vygotsky, who stated that "one step in learning may actually mean one hundred steps in development" (Bodrova, 1997, p.21). In this study, the possible developmental influences of collaborative games in the Grade 6 mathematics classroom was explored. The focus of the research was on the practical application of learning content in the form of collaborative games that will promote development in mathematics.

It was the aim of this study to:

a. Determine how collaborative games could influence the mathematical development of learners in Grade 6;
b. Detect and analyse learner development when collaborative mathematical games are implemented in the classroom, and to see whether interest in and enjoyment of mathematics were engendered;

c. Promote the use of collaborative games in the mathematics classroom; and
d. Raise awareness regarding the influence that collaborative games have on a learner's mathematical development.

The advantages of learning through educational games could possibly include a positive influence on learners' mathematical development, which would lead to teachers being motivated to incorporate games into their teaching.

1.6 RESEARCH QUESTIONS

The following primary and secondary research questions guided this study:

Primary research question:

How do collaborative games influence learners' development in the Grade 6 mathematics classroom?

Secondary research questions:

1. How are educational games beneficial to learning and development in mathematics?
2. How does collaboration influence learning and development in mathematics?

1.7 METHODOLOGICAL CONSIDERATIONS

For this study, a qualitative approach was used, although both qualitative and quantitative data was collected. Three data collection methods were used: intervention (pre-test - post-test design), observations, and interviews. The intervention was implemented in the second school term of 2017. During the intervention period of four weeks, learners completed one pre-test and one post-test every week on each of the following four mathematics topics: multiplication, nets of 3D objects, symmetry, and division. The pre-tests included activities from the Grade 5 mathematics textbook (pre-knowledge), which was completed by all the participants at the start of a week. Of the four Grade 6 classes, two classes were assigned to the experimental group, and the other two to the comparison group. For the post-test, the comparison group completed a textbook activity, while the experimental group completed the same questions, but in a collaborative game-based worksheet format that was designed in accordance with the specifications of the Curriculum and Assessment Policy Statement (CAPS) document. All four classes were observed during their mathematics period, only on Fridays when the post-tests were scheduled, and while the content was being taught. The post-test was then completed afterwards. The mathematics teacher taught all of her classes, facilitated the post-test, and participated in two interviews (including the same questions), one before, and one after the intervention period.

1.8 CONCEPT CLARIFICATIONS

The literature uses these concepts in various different ways, and so it is important to understand how they have been used in this study:

- Game influence and effect: games could influence and affect learners' way of learning, their understanding of mathematics, and could lead to an increase in their mathematical development.
- Games: games include fun, motivation, interest, creativity, opportunity for collaboration, participation, engagement, challenges, fine motor skills, gross motor skills, speech/language skills, cognitive/perceptual skills, and learning (Ramani & Eason, 2015; Kurtz, 2014).
- Educational games: according to the Game Object Model (GOM), the following elements are important in educational game design: play, exploration, challenges, engagement, critical thinking, discovery, goal formation, goal completion, competition, practice, fun, interaction, visual, logical, mathematical, computational, short-term memory, and long-term memory (Amory, Molomo & Blignaut, 2011).
- Mathematics game-based worksheet: this is the worksheet that I designed using the questions from the Grade 6 mathematics textbook, keeping to the specifications of the CAPS document and adding the elements of an educational game. It was focused on learning content,

making learning fun, promoting learner engagement through collaboration, and increasing learner development in mathematics.

- Collaboration: this refers to learners working together, helping each other, explaining their thought process, and making joint decisions (Plass et al., 2013). Cooperation is further referred to as collaboration, which is the behaviour required to work with others (Capar & Tarim, 2015).
- Engagement: engagement is a term used in the literature, which is also referred to as collaboration in this study. Engagement could take place in the form of small group work, involvement in class, taking part in class discussions and games, and working with peers to increase their development in mathematics. It is one of the intentions of educational games not only to engage with others, but to increase engagement in educational activities (Plass et al., 2013).
- Differentiated instruction: to address diverse learning needs by incorporating differentiated educational games (Trinter et al., 2015).
- Learner development: according to the CAPS document, mathematical development includes development in any of the following areas: a critical awareness of mathematical relationships (social, environmental, cultural and economic relations), confidence and competence, curiosity and love for mathematics, appreciation of mathematics, creativity, recognition of mathematics as part of human activity, deep conceptual understanding, and an acquisition of specific knowledge and skills (Department of Basic Education, 2011).
- Learner achievement: the quality of early mathematical experiences is one of the main determinants of later achievement (De Vries, Thomas & Warren, 2010). Achievement is a result of an increase in a learner's mathematical development, which, in this study, may be due to the incorporation of collaborative game-based worksheets.
- Cognitive levels: according to the CAPS document, assessments should include four cognitive levels, which are knowledge, routine procedures,

complex procedures, and problem-solving (Department of Basic Education, 2011).

- Cognitive level ‘knowledge’: this is the first level, which describes skills such as “estimation and appropriate rounding off of numbers; straight recall; identification and direct use of correct formula; use of mathematical facts; appropriate use of mathematical vocabulary” (Department of Basic Education, 2011, p. 296).
- Cognitive level ‘routine procedures’: this is the second level, which describes skills such as “perform well-known procedures; simple applications and calculations, which might involve many steps; derivation from given information may be involved; identification and use (after changing the subject) of correct formula generally similar to those encountered in class” (Department of Basic Education, 2011, p. 296).
- Scaffolding: the Zone of Proximal Development consists of a lower level (independent performance), and an upper level (the most a child can do with assistance) in which scaffolding occurs (Bodrova, 1997). This means that learners build onto their existing knowledge to achieve their highest potential with the assistance of a more knowledgeable other.
- Play: play refers to a player showing ownership, control, and competence. Specific to mathematics, play involves creativity, curiosity, problem posing, and problem solving (Dockett & Perry, 2010).
- Sensorimotor: sensorimotor is a combination of sensory and motor aspects during physical activities.
- TIMSS: 4th and 8th graders are assessed by TIMSS, which measures the trends in mathematics and science achievement. It provides warnings where the curriculum requires reform, as well as a measure of the effectiveness of such reforms (IEA, 2017).
- AMESA: the Association for Mathematics Education of South Africa represents the interest of mathematics at a provincial and national level, which includes co-organising the South African Grade 4-7 Mathematics Challenge consisting of two rounds of question papers. The challenge

aims to enhance the quality of the teaching and learning of mathematics (AMESA, 2017).

- Conquesta: Conquesta Olympiads provide question papers that follow the CAPS curriculum, and are written in some independent schools and government schools across South Africa, as well as those of some neighbouring countries. Conquesta's purpose is focused on learners' self-esteem and confidence. It also acknowledges learners' efforts despite their achievement in terms of the question papers (Conquesta Olympiads, 2007).

1.9 INTRODUCTION TO THE LITERATURE REVIEW

A literature review will follow in Chapter 2 of the dissertation. The literature review explores how learners develop in mathematics when playing collaborative games, the effect of learners' development on their achievement, and their attitudes towards mathematics. It further includes how learners learn, construct, and discover knowledge, and what a quality educational game should comprise.

Play is intended to support development in mathematics, even though there is no guarantee that development will take place. Play is promoted as one of the means of awakening learners' natural curiosity, recognising that mathematics is a social activity, and relating mathematics to their everyday lives (Dockett & Perry, 2010). Enjoyment during play is one of the elements of a sensorimotor learning game, which helps learners to develop physically, cognitively and socially (Kurtz, 2014). Furthermore, play could affect the way learners perceive an activity, and enjoy it, could have a more lasting effect on learners' development.

Learning and the construction of knowledge can also be facilitated by play. This involves integrating experiences and understanding, which allows learners to create their own meaning from it (Dockett & Perry, 2010). When playing, learners have the opportunity to practice scaffolding information through interacting with someone more knowledgeable or with more experience than themselves (Dockett & Perry, 2010). From a constructivist perspective, learners create their own meanings from their individual experiences (Ertmer & Newby, 2013). This perspective allows learners to be accountable for their own learning, and when arranged into small groups, learn from each other and thus add to their knowledge.

According to Cojocariu and Boghian (2014), game-based learning connects learners and provides an opportunity for active learning. When learners are working together in groups, they use their group as support when they need help, but remain accountable for their own learning (Ter Vrugte et al., 2015). Games include the element of collaboration, which could be beneficial for learners in gaining knowledge from each other, or helping each other when the teacher is not able to provide individual attention to each learner due to limited time.

In a study comparing individual learning with collaborative and competitive modes of learning, it was found that when learners worked in small groups, they dealt better with complex information and problem solving (Plass et al., 2013). Problem solving is one of the many disciplines that develop through collaborative learning (Cojocariu & Boghian, 2014). Thus, games that include collaboration may support learners' development.

Games come in many different formats when taking the content and objectives of a lesson into account. Therefore, game design is a flexible task that requires thought and creativity (Trinter et al., 2015). It is important to design educational purposes into a game for it to be educational, which could include teaching a learner, broadening concepts, developing skills, or gaining a better understanding of a matter (Cojocariu & Boghian, 2014). The Game Object Model, which is used to design digital educational games, specifies qualities such as interaction, fun, play, engagement, challenges, critical thinking, competition, and practice, to name a few, as some of many attributes of a quality educational game (Amory & Seagram, 2003; Amory et al., 2011). A good starting point for a teacher could be to get to know his/her learners and find out what their interests are before designing a game or game-based worksheet.

As seen in this section, a game could be used as a vehicle that facilitates social and academic development. Through collaboration, learners may support each other on their learning journey. Although games and collaboration may work for one area of mathematics, it may not have the same effects in another area in mathematics. The influences that games and collaboration have on learners' development in mathematics are further explored in Chapter 2.

1.10 THE STRUCTURE OF THE DISSERTATION

This dissertation consists of five chapters, a list of references and addenda. Chapter 1 is an introduction to the dissertation, which includes the background, problem statement, purpose of the study, research questions, and methodological considerations. Concept clarifications, an introduction to the literature review, limitations, and possible contributions of this study are also provided in this chapter. Chapter 2 consists of the literature review and theoretical framework. The literature provides a deeper understanding and knowledge that could be useful when forming conclusions. The theoretical framework, on which the study is based, is explained at the end of Chapter 2. Chapter 3 provides the research methodology, according to which the study was conducted. Within the methodology, the following is explained: the research philosophy, methodological choices, research techniques, and data collection instruments. Following the explanation of data collection instruments, the data analysis and interpretation, trustworthiness, and ethical considerations are discussed. In Chapter 4, the data obtained through the intervention, observations and interviews, will be discussed. The literature review and theoretical framework were used together to understand the data obtained and discussed in the study, which will ultimately lead to answering the research questions. Chapter 5 is the final chapter, containing the summary, discussion of the research questions, conclusions, implications and recommendations for future research, limitations, and final reflections. A list of references is included, followed by the addenda mentioned throughout the dissertation.

CHAPTER 2 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

The following ideas will be discussed in the literature review of this chapter: the influence of games and collaboration on learners' development; learning and the construction of knowledge; and quality educational games. This chapter also includes the theoretical framework and the design of the educational game-based worksheets used in the intervention phase of this study. The following main headings were chosen as they relate to the ideas explored through this study, and are included in the following order: the influence of games and collaboration on learners' development; learning and the construction of knowledge; quality educational games; and the theoretical framework of this study. Each main heading is elucidated in sub-headings in an attempt to provide a complete understanding of each main heading. The following main headings are followed by their own short introduction where the sub-headings are introduced before they are discussed.

2.2 The influence of games on learners' development

Games have the potential to create an environment for active learning that includes elements such as fun, social contexts, motivation, and creativity (Cojocariu & Boghian, 2014). The teacher's influence in guided play will determine the quality at which the above-mentioned elements will be created. This section of the literature review discusses: the opportunity to learn; skill development through game-based learning; and the effects of games on learners' motivation and positive attitudes towards the learning process.

2.2.1 The opportunity to learn through play

Ramani et al.'s (2012) study on playing number board games showed an increase in four different variables: estimation accuracy, magnitude comparison, number identification, and counting. According to Dockett and Perry (2010), play in mathematics does not guarantee mathematical development, but it can support development in the following areas: curiosity, recognising mathematics in social environments, and promoting the relevance of mathematics in everyday lives, which is linked to the developmental areas that the CAPS document aims to achieve (see Chapter 1, Section 1.9). These three areas are included in the ‘specific aims’ heading of the CAPS document, which teaching and learning of mathematics purposes to develop (Department of Basic Education, 2011).

The teacher’s ability to facilitate play in an adequate way will determine the role that play carries out in children’s mathematical thinking (Dockett & Perry, 2010). Guided play links activities to the curriculum and promotes learning by creating opportunities for exploration and learning (Trinter et al., 2015). For instance, teachers can engage learners in reflection and provide the opportunity for them to present the mathematical ideas that they have discovered through play (Dockett & Perry, 2010). Considering the literature, one approach in creating the opportunity to learn is through playing games.

In a study comparing learners who play a game, and learners who completed paper-and-pencil drills, learners who played the game (The Math App), demonstrated improved performance in mathematics (Chang, Evans, Kim, Norton & Samur, 2015). The above-mentioned study that compared a game to paper-and-pencil drills provides findings that are consistent with other studies where academic achievement has been promoted through learning games (Chang et al., 2015). Different games produce different results in learner development and achievement, which is why it is important to know about the different types of games that a teacher could use to achieve specific outcomes. This will be discussed in Section 2.5.

2.2.2 Skill development through game-based learning

Children spend time playing with peers, which allows them to practise their existing skills, but also to learn new skills (Trinter et al., 2015). During game-based learning, learners use skills such as synthesis, analysis, evaluation, and critical thinking to solve problems (Chen & Law, 2016). Learners not only develop skills in disciplines such as leadership, team-work, communicative and interaction skills, but also in problem solving, creativity, logic, and decision making (Cojocariu & Boghian, 2014). Research has suggested that conceptual knowledge and skill acquisition are related, therefore development in one of these could benefit the other (Plass et al., 2013). During early childhood, arithmetic skills develop, such as solving basic problems where all four operations (addition, subtraction, multiplication and division) are used (Plass et al., 2013). In a study done on middle school-age learners, a game was designed to support skill automation when solving arithmetic problems, and small-group collaboration was found to be beneficial in the development of arithmetic skills (Plass et al., 2013). For learners to develop physically, cognitively, and socially, and for their fundamental needs to be fulfilled, one game may not be able to achieve all of these. Dockett and Perry (2010) support the idea that mathematical development is not guaranteed through play, but could provide great possibilities. Although there is limited research in favor of collaborative gameplay over individual gameplay, the positive effects of collaboration have been reported through some studies on learning, attitudes, gameplay, motivation and engagement (Ter Vrugte et al., 2015).

2.2.3 Effects of games on learners' motivation and positive attitudes towards the learning process

A decrease in play time has been shown to affect a child's development (Bodrova, Germeroth & Leong, 2013). According to the studies being done on 4th and 8th graders by TIMSS every four years, the results show that the older learners get, the more they develop a dislike for mathematics, regardless of their achievement in the subject (Mullis et al. 2016). Game-based learning plays a role in creating positive attitudes towards learning, developing memory skills, connecting learners, and assisting learners in self-constructed learning (Cojocariu & Boghian, 2014). Apart from learning the content, mathematics can become enjoyable, motivating and interesting to learners when completing a game-based activity (Ramani et al., 2012). An interest in mathematics develops through play and informal activities (Ramani et al., 2012). Such interest in mathematics may motivate learners to engage in active learning (Cojocariu & Boghian, 2014). When teachers facilitate a connection between learners' personal experiences, interest in the game, and school knowledge, it could support learners' gameplay and classroom learning goals (Foster & Shah, 2015). As a result, motivational habits exist through the playing process, such as self-regulation and interest in classroom learning goals (Foster & Shah, 2015). Therefore, teachers play an important role in enhancing learning and motivation (Foster & Shah, 2015). It is possible that developing an interest in a subject and having fun may automatically motivate a learner to take part actively in the learning process.

2.2.4 Summary

Implementing play in the form of games in the classroom should be done with guidance from the curriculum, and should be aimed at achieving the skills that are set out in the CAPS document. Games include development in areas such as critical thinking, problem solving, decision making, logic, and creativity. The elements of games have a positive influence on learners' motivation and attitude towards the learning process through creating an interest in mathematics due to it being fun and enjoyable.

2.3 THE INFLUENCE OF COLLABORATION ON LEARNERS' DEVELOPMENT

Games provide learning environments in which learners have the opportunity to engage (Amory, 2007) and help each other. It is therefore important to enable children to play and learn. This is corroborated by Vygotsky, who promoted the opportunity to learn in the Zone of Proximal Development (further referred to as ZPD) (Bodrova et al., 2013). This opportunity may allow learners to learn without them realising it because they are playing. The addition of collaboration with others and the influence thereof on learners' development will be elaborated on in this section. This section discusses: learning, development and achievement through collaborative gameplay; skill development through collaboration; and the effects of collaboration on learners' motivation and positive attitudes towards the learning process.

2.3.1 Learning, development and achievement through collaborative gameplay

Early childhood settings and mathematics learning raise concern due to the relationship between early mathematical knowledge and later achievement (De Vries et al., 2010). Apart from developing socially through collaboration, learners also experience higher achievement due to cognitive effects (Pareto, Haake, Lindstrom, Sjoden & Gultz, 2012). These cognitive effects include higher order problem solving through reasoning and making decisions (Pareto et al., 2012). Collaborative learning seems to be helpful when learners need to demonstrate problem solving. This could be due to many minds thinking and brainstorming together instead of one learner using only his/her knowledge and understanding. In Plass et al.'s (2013) study, conceptual knowledge instead of skill acquisition increased when collaborative play took place. Therefore, collaboration has beneficial performance effects on learners' tasks where conceptual knowledge needs to be demonstrated (Plass et al., 2013). When opportunities to demonstrate conceptual knowledge are provided by the teacher, learners may develop their understanding of mathematics and be active participants in their development towards higher achievement in mathematics.

Play is not only viewed as a vehicle for learning, but also a context in which learners' own learning can be demonstrated, while it also scaffolds the learning of others when playing together (Dockett & Perry, 2010). The ZPD has been described as "the optimal window of instruction offering the best opportunities for a child to learn and to develop" (Bodrova, 1997. p. 21). The ZPD facilitates scaffolding where a learner builds onto their existing knowledge and reaches their highest potential with the assistance of a more knowledgeable other. Collaboration provides an opportunity for scaffolding to occur in the ZPD, which involves a more knowledgeable person assisting a learner to achieve the most that he/she can do (Bodrova, 1997). Collaboration may facilitate the opportunity for scaffolding in the ZPD where learners gain knowledge from more knowledgeable peers (Bodrova et al., 2013). Involving learners through play provides them with the opportunity to interact with more knowledgeable or experienced peers (Dockett & Perry, 2010). In collaborative settings, the teacher may strategically group learners according to their achievement levels in order to provide the low-achieving learners with support from high-achieving learners in their group. However, heterogeneous groups may only be beneficial to low-achieving learners during collaboration (Ter Vrugte et al., 2015). This idea and other effects that heterogeneous groups have on collaboration and competition will further be discussed in Section 2.4.1.

In one study, the 'Cross Number Puzzle' game was adapted into a learning activity on a technology platform, which was completed by learners either collaboratively (Class A) or individually (Class B) (Chen, Looi, Lin, Shao & Chan, 2012). In both classes, when learners were uncertain, they could request 'tips' from the game (Chen et al., 2012). Class A worked collaboratively and relied less on the 'tips' than Class B because they had each other for assistance (Chen et al., 2012). Thus, according to the study's conclusion, collaboration assisted learners in problem solving and enhanced learning in Class A (Chen et al., 2012). The study found that from both classes, the low-achieving learners used these 'tips' more than the high-achieving learners (Chen et al., 2012). Therefore, between the high-achieving and low-achieving learners, the low-achieving learners benefited the most from the game (Chen et al., 2012). The support that low-achieving learners receive during collaboration may motivate low-achieving learners to learn collaboratively and not only rely on their own abilities and knowledge or feel alone in their struggles. This may be frustrating for high-achieving learners when working in heterogeneous groups because low-achieving learners seem to need more support, where high-achieving learners need less support and could achieve the same results in a collaborative setting or by working individually.

2.3.2 Skill development through collaboration

Working in groups may foster creativity due to the diversity brought into the group by different learners (James, Gerard & Vagt-Traore, 2010). A study that combined the use of collaboration and competition found that this combination contributes to creativity during game-playing, and engages learners with the subject matter more fully (Pareto et al., 2012). Games play a role in meeting many fundamental needs like enjoyment, involvement, structure, motivation, creativity and social interaction (Cojocariu & Boghian, 2014). Apart from fundamental needs that should be met, learners also require development in other areas - physically, cognitively and socially. According to Kurtz (2014), physical, cognitive and social development can be achieved through play, especially when it is an enjoyable activity. Furthermore, one of the developmental milestones in learners' development include play skills (Kurtz, 2014). Since it is difficult for a teacher to provide individual attention to each learner, this type of engagement could simplify and help with the learning process. Mathematical games and collaboration with others give learners the opportunity to work together and achieve success together instead of the teacher helping each learner individually.

Learners develop social skills when collaboration is incorporated (Pareto et al., 2012). Social benefits could be achieved through opportunities to demonstrate interactions that underpin mathematical thinking, such as innovative thinking, risk taking, and problem solving (Dockett & Perry, 2010). When play involves social interaction, it facilitates joint meaning making by testing, explaining, and sharing learners' perspectives and understanding while others also do so (Dockett & Perry, 2010). Therefore, learners have the opportunity to develop skills through collaboration that they might not otherwise use if they were working individually.

In a study done with learners working individually compared to learners working collaboratively on a computer game, collaboration was found to enhance the effectiveness of learning (Chen et al, 2012). The learners who played the game collaboratively made better progress than the learners completing it individually (Chen et al., 2012). Another study comparing individual, collaborative and competitive modes of learning found that learners dealt better with complex information and solving problems when working in small groups than when they worked individually (Plass et al., 2013). In a different study, learners collaborated in pairs or competed in pairs, and shared game playing insights during collaboration, as well as competing (Pareto et al., 2012). Group competition in a collaborative setting can positively influence learners' interdependence and individual accountability (Ter Vrugte et al., 2015). In a comparison between learning tasks and individual learning tasks, most of the literature shows more positive effects from the use of collaboration.

After reviewing the literature, it can be concluded that development is not guaranteed through collaborative gameplay. Thus, implementing a game-based worksheet through collaboration that includes the learners' involvement, fun, and a better understanding could be used to support learners' development in mathematics.

2.3.3 Effects of collaboration on learners' motivation and positive attitudes towards the learning process

Development in positive attitudes has specifically been demonstrated at primary school level, where they play games in collaboration (Trinter et al., 2015). According to Chen and Law (2016), collaboration develops positive attitudes and stronger motivation in learners towards tasks. Supporters of game-based learning find that learners are motivated to learn through the use of educational games (Chen & Law, 2016). Positive perceptions of mathematics relate to lower anxiety when dealing with mathematics, and could also lead to higher achievement in mathematics (Katmada et al., 2014). Mathematics proficiency may be impacted by learning games through improving learners' attitudes towards mathematics, and as a result, this may have an impact on learners' mathematical performance (Chang et al., 2015). Motivation to learn may be one of many obstacles that hinder a child's learning process. Positive attitudes and motivation may be engendered during collaboration, and when a task is taken on with a positive attitude and motivation, it could promote achievement. In contrast with what is being said, Japan and Korea, who participated in TIMSS in 1995 and 2015, were two of the highest achieving countries, but also showed the highest of percent of discontent towards mathematics (25%) (Mullis et al., 2016). Although discontent regarding mathematics is not the only negative influence on learners' achievement in the subjects, it plays a role in learners' development since appreciation, curiosity, and a love of mathematics are some of the developmental areas in mathematics.

In one study, general learning and motivation were influenced by playing educational games (Pareto et al., 2012). In another study where individual, competative and collaborative modes of learning were compared, the literature shows collaboration to be helpful for motivation and learning (Plass et al., 2013). When collaborative settings were compared to competitive settings for learning, learners were positively impacted by the presence of peers when learning, and demonstrated more positive attitudes towards mathematics (Plass et al., 2013). This could be due to the motivation that learners have to learn when they get to work together and play a game, instead of falling into a routine where learners are required to work from their textbooks.

2.3.4 Summary

Learners develop mathematically through the incorporation of games and collaboration. It was seen in the literature that games have benefits for learners' development such as curiosity about, and a recognition of mathematics in society. However, games also provide the opportunity for learners to collaborate with each other, which also influences their development positively in areas such as creativity and problem solving. Considering Section 2.2, a combination of games and collaboration can positively influence learners' development, motivation, and attitude towards mathematics more than when implementing each in isolation.

2.4 Learning and the construction of knowledge

Knowledge refers to how meaning is created through an individual's own experience when viewed from a constructivist's perspective (Ertmer & Newby, 2013). Learning and the construction of knowledge may be better understood through a discussion under the following sub-headings: learning in collaboration through heterogeneous groups; discovery learning; understanding mathematics; and knowledge construction through experience.

2.4.1 Learning in collaboration through heterogeneous groups

Learners benefit by explaining to others, constructing accurate knowledge, and providing less able learners with support through heterogeneous groups (Ter

Vrugte et al., 2015). However, during competition, heterogeneous groups put low-achieving learners at a disadvantage due to high-achieving learners becoming more dominant, while the participation of below average learners decreases (Ter Vrugte et al., 2015). Considering the study described in Section 2.2.2 on the 'Cross Number Puzzle' game, Class A, which worked collaboratively, relied more on each other than the game 'tips' (Chen et al., 2012). Taking into account that in both classes the low-achieving learners used the game 'tips' the most, it may indicate that low-achieving learners will benefit more from heterogeneous groups because there are high-achieving learners in the group that could also provide support, the same way in which the game 'tips' aim to do. It may also mean that the high-achieving learners would have been able to achieve the same results even if they were working either collaboratively or individually.

When a typical academic task is completed in heterogeneous groups, the more able learner is turned to for help, which leads to little interaction as it becomes a process of giving or receiving answers (Noddings, 1989). Even though all of the group members have the right answer, their understanding is minimised and interferes with learning (Noddings, 1989). Working in heterogeneous groups could be frustrating for high-achieving learners because they might have been able to finish the game quicker without having to explain to others or be the one to give all the answers. The fact that learners accessed the game 'tips' shows that there is a need for support, which could be provided through heterogeneous groups. This could be helpful to teachers in that low-achieving learners can perform when they receive the support they need.

When group learning is used in mathematics, it helps to eliminate learners' frustration due to the additional help and support that it offers (Ke & Grabowski, 2007). According to a study on collaborative techniques, positive interdependence and individual accountability have resulted in positive effects on achievement (Ter Vrugte et al., 2015). Positive interdependence means that one learner's accomplishments contribute positively to the other group members' accomplishments, meaning that the group members receive the same recognition for the group's accomplishments (Lou et al, 1996). The unfortunate result of this is that it adds to high-achieving learners' frustration and demotivates them to participate in collaborative settings where heterogeneous grouping is used because the high-achieving learners are able to do most of the work, but the low-achieving learners receive the same marks for the work done by the high-achieving learners. While collaboration is beneficial to low-achieving learners, competition could demotivate them to participate due to tension, anxiety, frustration and feelings of inferiority (Ter Vrugte, et al., 2015).

Heterogeneous groups benefit learners on an academic and social level (Loreman, 2007). Knowledge construction has been described as a social and collaborative process (Plass et al., 2013). Moreover, the impact that social contexts and peer interaction have on the learning process have long been established (Plass et al., 2013). Learners could take on the role of a peer tutor who has social similarities, who are not professionals, but are able to help another learner learn; and through tutoring others, they themselves learn, which is otherwise known as learning by teaching (Worley & Naresh, 2014). Within heterogeneous groups, learners could be completing individual work, but have the support of someone more knowledgeable (Dockett & Perry, 2010). When using this approach to group learning, less able learners have a source of support from which they can access information when needed (Ter Vrugte et al., 2015). This could help learners take responsibility for their own learning and knowledge construction with the support of someone helping to fill in the gaps.

Learners get involved in learning when explaining to each other and co-constructing knowledge (Plass et al., 2013). Opportunities for scaffolding arise through collaboration where learners share differences in their own ideas, ask questions, and explain their own reasoning in finding solutions (Chen & Law, 2016). As mentioned previously, it is possible for the scaffolding of knowledge in the ZPD in a game setting where learners collaborate and learn from each other,. It is here that heterogenous groups provide diversity in perspectives, ideas and explanations.

2.4.2 Discovery learning and scaffolding through collaboration

Bruner's Theory of Learning, namely, discovery learning, involves encouraging learners to make informed guesses using a variety of media, resources and games, and allowing learners to explore their curiosity (Du Plessis et al., 2007). Collaborative learning promotes discovery, comprehension and problem-solving skills (Du Plessis et al., 2007). This could be due to learners being able to discover new knowledge when grouped with more knowledgeable peers. As mentioned before, comprehension and problem-solving skills are developed during small-group work (Plass et al., 2013). Through small-group work, discovery learning can be implemented and these groups may provide learners with the opportunity to discover new knowledge from each other and as a result, also be each other's resources.

One study compared collaboration and competition, as well as a combination of the two, by grouping learners into teams of two, which allowed each learner the opportunity to perform well in individual instructional tasks afterwards (Ter Vrugte, 2015). In situations where play is involved, scaffolding occurs due to a child interacting with someone more knowledgeable or with more experience than themselves (Dockett & Perry, 2010). This could be linked to Vygotsky's ZPD where scaffolding takes place and learning occurs. The collaborative element of games allows learners to help each other learn and then use their knowledge to continue individually (Ter Vrugte, 2015). A child is assessed not only in isolation, but also in terms of his/her ability to absorb instructional support from another person (Bodrova, 1997). This may be very helpful for low-achieving learners because they receive the support to acquire knowledge and skills from peers who are high-achieving learners and more knowledgeable than they are.

2.4.3 Development in understanding mathematics through games

Mathematics contain facts, but also requires understanding, which could mean that there is a great connection between play and mathematics (Dockett & Perry, 2010). When guidance and fluency during a game are provided by skilled educators, learners' mathematical knowledge and understanding can be promoted (Dockett & Perry, 2010). In one study, pre-service teachers were asked to develop a game that would help learners gain mathematical knowledge and be able to implement it (Ramani & Eason, 2015). Their games were creative, attractive and engaging, which helped learners to practise a range of skills, as well as gain conceptual understanding in the specific learning area (Ramani & Eason, 2015).

Such games provide an opportunity for knowledge development as scaffolding the learning process assists learners to attain levels of understandings that would not have been attainable without assistance (Chen & Law, 2016). Cognitive structures also develop through collaboration and as learners are exposed to different ideas, they can ask questions and can reason using their own understanding (Chen & Law, 2016). Collaboration, where scaffolding is involved and combined with the enjoyment of a task could lead to meaningful interaction, facilitating learning, and knowledge construction. This helps learners to understand concepts rather than simply learning procedures as a prerequisite for passing mathematics.

2.4.4 Knowledge construction through experience

Play integrates experience and understanding by connecting learners' past experiences with current experiences, exploring them, and creating their own meaning from them (Dockett & Perry, 2010). Game-based learning allows for deliberate practise and the construction of formal and semantic knowledge (Chen & Law, 2016). Practise, as well as different forms of experience, cause learning to take place (Ertmer & Newby, 2013). Experiences (living and doing) aid learning in children, for example, when playing with building blocks, children become aware that the number of blocks will increase when they put another one on top (Mayesky, 2009). When practising in groups, learners may have different experiences every time due to the diversity in learners. Meaningful experiences could arise from every situation where learners practise together. Practising a new skill such as building blocks can be designed into a fun game. Learners may find it easier to remember concepts when the experience was enjoyed.

2.4.5 Summary

Incorporating collaboration into the learning process involves correct groupings. Heterogeneous groups were explained to be the most beneficial to struggling learners as these function as support for these learners. Collaboration facilitates the ZPD and allows learners to build onto their existing knowledge using the knowledge of high-achieving learners. In addition, learners develop problem-solving skills, especially when working in small heterogeneous groups, while sharing ideas, asking questions, and explaining to each other.

2.5 QUALITY EDUCATIONAL GAMES

Educational games have educational purposes and educational value, which include teaching people, broadening concepts, reinforcing development and understanding, and assisting in skill acquisition (Cojocariu & Boghian, 2014). "One step in learning may actually mean one hundred steps in development" (Bodrova, 1997, p. 21). When a game is designed to promote learning, it could benefit learners' development even more and give more reason to design quality educational games. Within this section, the following will be discussed as contributing to knowledge on quality educational games: the purpose of quality educational games; differentiation through quality educational games; incorporating collaboration and competition; and educational game design and application. This section precedes a further detailed discussion on the theoretical framework used in this study.

2.5.1 Educational games

The Game Object Model describes educational games as engaging, supporting authentic learning in social contexts, and challenging (Amory et al, 2011). Amory (2007) suggests that gameplay supports development through visualisation, experimentation, and creativity. Interventions and activities that are designed appropriately may assist in learners' mathematical development (Hunting, 2010). It is important for teachers to know the difference between games and educational games in order to reach specific outcomes that will develop learners on an academic level.

When teachers incorporate computer games into the classroom, this is thought to contribute to more contemporary educational practices by offering an engaging learning environment (Amory, 2007). Even though mathematical development is not guaranteed, by keeping play and development in mathematics in mind, it is possible to design an educational game that will offer support in learners' mathematical development (Cojocariu & Boghian, 2014). Games may not be the answer to every problem, and cannot be used to develop every specific aim set out by the CAPS document, but they can be used as a helpful teaching method that lends support to accomplish the aims of teaching and learning mathematics.

2.5.2 Facilitating differentiation through educational games

Learners differ in their mathematical readiness, mathematical conceptions, and learning profiles (Trinter et al., 2015). Learners' diverse needs can be addressed through differentiated instruction, which includes incorporating differentiated educational games (Trinter et al., 2015). Educators should emphasise the value of mathematics, and develop mathematical skills in learners and learners' belief in their own ability to succeed (Katmada et al., 2014). Keeping educational outcomes in mind, good practice incorporates different methods of teaching and learning that will facilitate and support learners' development and meet their needs while doing so.

Teachers should seek topics that lend themselves to games and integrate informal learning activities into direct classroom instruction (Ramani & Eason, 2015). By using preferred learning styles, learners get involved and have fun, which leads to a better understanding and makes the content more memorable (Hardy, 2008). Games can be incorporated into mathematics lessons as a supplement, and be used as an intervention for learners who battle (Ramani & Eason, 2015). Addressing different learning styles, games can be designed to cater to learners that learn visually, auditorily and physically.

2.5.3 Incorporating collaboration and competition into games

Collaboration involves learners working together, whereas competition involves working against each other (Ter Vrugte et al., 2015). In a study, a game was measured on being played either individually, collaboratively, or competitively. The results suggest that the game was more exciting and personally relevant when played either collaboratively or competitively than when being played alone (Plass et al., 2013). A different study's findings show that collaborative settings are preferred over competitive, or a combination of the two approaches (Pareto et al., 2012). A combination of collaboration and competition was applied in one study and referred to as group competition (heterogeneous grouping) where collaboration maximised learners' individual knowledge, and afterwards, the learners continued working individually (Ter Vrugte et al., 2015). The purpose of heterogeneous teams is to help each individual learner to perform well in an instructional tournament (Ter Vrugte et al., 2015). In contrast, competition could bring about tension, anxiety, and frustration in learners, which could distract them from the educational content (Ter Vrugte et al., 2015). When teachers design a game, they should take heterogeneous grouping into consideration when deciding on a collaborative or competitive approach to the game that they design.

Collaboration and competition do not elicit the same degree of motivation in all learners or in all situations (Pareto et al., 2012). High ability learners are not affected by grouping, therefore collaboration should be used in support of low ability learners (Ter Vrugte et al., 2015). Nevertheless, it is still important to take a specific type of problem into consideration to establish whether competition or collaboration is the best approach (Pareto et al., 2012). For instance, when a teacher designs a game with educational objectives to either improve learners' conceptual knowlede, problem solving skills, or to offer support to low-achieving learners, collaboration would be appropriate (Plass et al., 2013). In contrast, a teacher could use competition when the educational objectives include development in analytical skills or performance goal orientation, which is a demonstation and validation of learners' abilities (Plass et al., 2013). Considering the literature on the incorporation of collaboration and competition into educational games, it is a process of discovering the purpose of the approach, different levels of educational objectives, and defining the target group for the game.

2.5.4 Educational game design and application

Thought and creativity play a role in designing an educational game (Trinter et al., 2015). It remains difficult for researchers and game designers to design games that maintain motivational integrity that will guarantee learning (Ter Vrugte et al., 2015). Although there are many benefits to incorporating games into lessons, teachers find it difficult to do due to the amount of concepts and skills that need to be taught over a short period of time in order to meet all the requirements of the curriculum (Ramani & Eason, 2015). Therefore, teachers need the pedagogical competence to integrate games into their teaching that will support the learning process (Foster & Shah, 2015). However, it is not always necessary to develop a game because there are educational games that have already been developed to tie into mathematical concepts (Ramani & Eason, 2015). It may be a daunting task to take on when designing an educational game, but with the appropriate framework, for example, the Game Object Model, teachers may find this task easier. Even so, incorporating educational games that already exist could be helpful to the teacher in the sense that they become familiar with the skills and concepts that games could develop, as well as thinking about and developing their own game.

In the designing of an effective educational game, it is important to make the knowledge explicit and help learners to attain information through support (Ter Vrugte et al., 2015). Nonetheless, there is flexibility in game design, therefore games could be designed into different formats that will suit the specific content that is presented (Trinter et al., 2015). Different types of games include, for example, board games, card games, and video games (Cojocariu & Boghian, 2014). In addition to digital games that can be played on a PlayStation or computer, smartphones also include game 'apps' (applications) that can be downloaded and played on the device. Apart from different game formats, games can also be approached either collaboratively, competitively, or individually, for example, collaboration could be beneficial in game-based learning as a form of support to help learners extend their knowledge (Ter Vrugte et al., 2015). Educational purposes, as already mentioned, such as teaching learners, broadening their concepts, reinforcing development, and helping a learner understand and acquire skills could guide the teacher in maintaining the quality of an educational game (Cojocariu & Boghian, 2014).

Learners should feel competent in a game-based learning environment, and be able to complete the task (Chen & Law, 2016). If a task seems too difficult, learners could lose interest and disengage from it (Chen & Law, 2016). One of the characteristics of games include eliciting situational interest, which could arise spontaneously due to enhanced excitement from the social context (Plass et al., 2013). Good qualities in a game could include enjoyment, involvement, structure, motivation, creativity and social interaction (Cojocariu & Boghian, 2014). A game-based activity that consists of enjoyment, motivation, and that is interesting to a learner makes mathematics more enjoyable (Ramani et al., 2012). The social context may assist in the development of an interest in and love of mathematics. It could be that the social context provides learners who find a task to be too difficult with support from other learners.

A framework for game design, which was also used as the theoretical framework for this study, is the Game Object Model (GOM). The Game Object Model provides the different attributes of games that may be developed into educational games with educational purposes (Amory & Seagram, 2003). When applying a game in the classroom, a few helpful steps include introducing the game, announcing the title and aim, presenting the materials needed to complete the game, explaining the rules, performing a trial game, and evaluating the game after learners have engaged with it themselves (Cojocariu & Boghian, 2014). The literature described above may be helpful in providing a starting point for teachers to become empowered to incorporate educational games into the mathematics classroom. It also provides quality criteria for future digital learning resources and learning material in mathematics education.

2.5.5 Summary

Appropriately designed games include educational purposes that will support the aims of teaching and learning mathematics. Educational games function as a different method that could influence learners' development in mathematics. Educational games should be used as a supplement to lessons. Since collaboration and competition have positive influences on learning, and games can take on many different formats, these two elements can be incorporated into the execution of educational games. Game design is a thoughtful and creative process, although it remains a difficult task. A framework for educational game design can be used in order to design games that learners will enjoy playing and have fun learning from.

2.6 THEORETICAL FRAMEWORK

As mentioned in the literature review, and to name a few, educational games should include attributes such as playing, exploration, challenges, engagement, critical thinking, discovery, goal formation, goal completion, competition, practise, fun, logic, contain visual features, mathematical concepts, interaction, long- and short-term memory, and more. These are all used as guidelines to design elements of regular games into an activity that could be used as an educational game. Depending on the learning outcomes of a lesson, a teacher could use these attributes and design an activity into game-based learning.

Game-based learning, or educational games, is suggested by the literature to be more effective than traditional mathematical instruction (Trinter et al., 2015). For this study, the Game Object Model, further referred to as GOM, was used as the theoretical framework. GOM, which was first introduced in 2003, was adapted and is presented below in Figure 2.1.

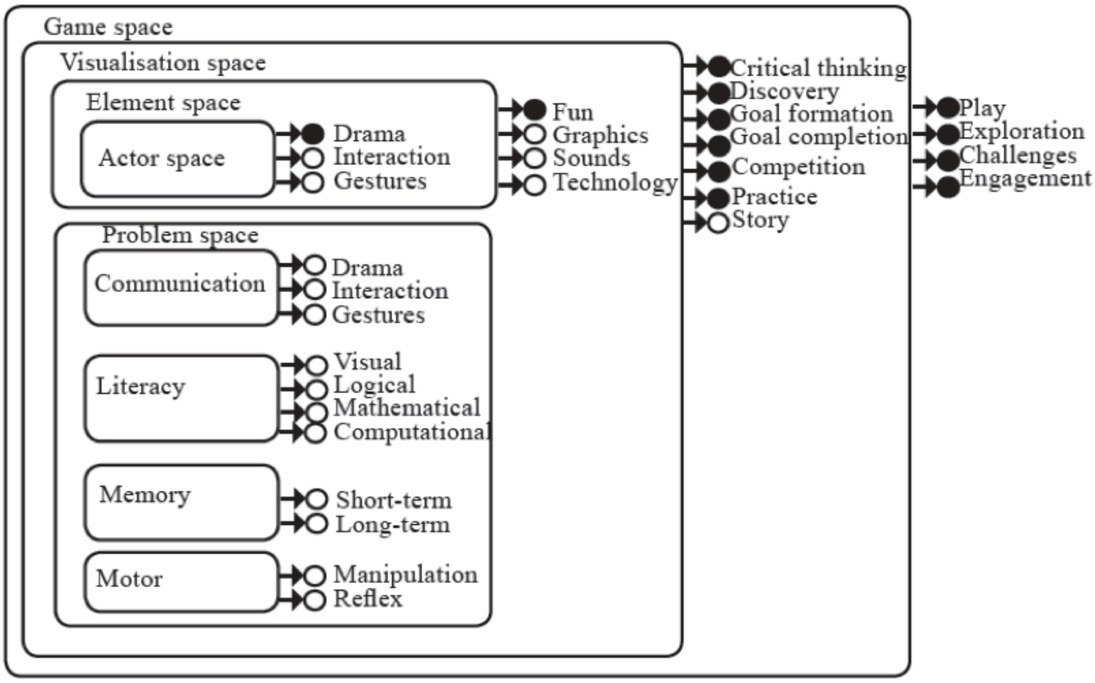

Figure 2.1: Visualisation of the Game Object Model (redrawn from Amory & Seagram, 2003) (Amory et al., 2011)

(● - *abstract interfaces,* - ○ *concrete interfaces)*

GOM is based on Object Oriented Programming concepts (Amory & Seagram, 2003). GOM was used in this study in order to design game elements into a worksheet that will promote educational objectives (Amory & Seagram, 2003). The model consists of pedagogical dimensions and game elements that are used to design a quality educational computer game (Amory & Seagram, 2003).

As seen in Figure 2.1, there are five components (objects) to an educational game: game space, visualisation space, element space, actor space, and problem space (Amory & Seagram, 2003; Amory et al., 2011). These spaces include abstract interfaces (closed circles) and/or concrete interfaces (open circles) (Amory & Seagram, 2003; Amory et al., 2011). When conceptualising and designing an educational game, abstract interfaces (attributes) are used, which refers to all pedagogical and theoretical constructs. Conversely, concrete interfaces (attributes) refer to design elements that are designed into game software (Amory & Seagram, 2003; Amory et al., 2011).

The game space includes playing, exploration, challenges, and engagement, all of which are motivational abstract interfaces (Amory & Seagram, 2003;

Amory et al., 2011). These abstract interfaces were included in the design of the game-based worksheets used in the intervention of this study, which allowed them to used as educational games (Amory & Seagram, 2003). The visualisation space includes critical thinking, discovery, goal formation, goal completion, competition, practise and story (Amory & Seagram, 2003; Amory et al., 2011). The element space includes fun, graphics, sound, and technology (Amory & Seagram, 2003; Amory et al., 2011). The actor space includes drama, interaction, and gestures (Amory & Seagram, 2003; Amory et al., 2011). The problem space includes literacy, communication, memory, and motor, which express the other visualisation interfaces, namely, story line, critical thinking, discovery, goal formation, goal completion, competition, and practice (Amory & Seagram, 2003; Amory et al., 2011).

Spaces are referred to as objects; these are represented by the rounded squares in Figure 2.1 (Amory, 2007). The inner objects inherit the outer object's interfaces. The inner objects contain mostly concrete interfaces, which are included in the game software and gameplay (Amory, 2007). The outer objects consist mainly of abstract interfaces, which are used when conceptualising game design (Amory, 2007). For instance, the visualisation space consists of the element space and problem space (Amory, 2007). The game space and visualisation space consist mostly of abstract attributes, which were included in the game-based worksheet used in this study. Many of these elements could be included in game-based classwork in the form of a worksheet that has quality educational objectives.

The specific components and their interfaces selected from the GOM were incorporated into the game-based worksheets for the intervention in this study. It also functioned as the predetermined codes used during the analysis phase of this study, which included:

a. The game space: play, exploration, challenges and engagement;
b. The visualisation space: critical thinking, discovery, goal formation, goal completion, competition, practice;
c. The element space: fun;
d. The actor space: interaction; and

e. The problem space: visual, logical, mathematical, computational, short-term memory and long-term memory (Amory & Seagram, 2003; Amory et al., 2011).

2.7 FINAL SUMMARY

The main headings of the literature review provide information to the reader on the influences of games and collaboration, and how they can be implemented to have an influence on learners' development in mathematics. Both games and collaboration have a positive influence on learners' development, with the condition that they be implemented appropriately. When development takes place, it can also have an effect on learners' achievement. The diversity of learners adds a diverse range of needs and skills to the mix, and these should be taken into consideration in teaching practices. Learners enjoy mathematics more when it is fun and interesting, and it then has positive influences on their motivation and attitude towards mathematics. The concern that teachers have in designing educational games may be reduced when considering that there is a model that can guide them in designing their own games. Such a model was used as, GOM, was used as the theoretical framework of this study.

The next chapter presents the research design used in this research, including the research techniques and procedures, quality criteria, data analysis and interpretation, and finally, the ethical considerations of this study.

CHAPTER 3 RESEARCH DESIGN

3.1 INTRODUCTION

This chapter describes the research methodology used in this study. The research design is provided in table format to summarise these decisions in an organised manner. Details of the research design, setting, research techniques and procedures, and data analysis and interpretation are provided. A timeline for the data collection process is organised in table format, and includes: dates, data collection instruments, sources, content and participants. The selection of participants and sampling methods are explained before a detailed discussion of the data collection process. The data collection methods, and thereafter the data analysis and interpretation techniques, are explained. Quality criteria in terms of trustworthiness and ethical considerations are also included in this chapter.

3.2 RESEARCH PHILOSOPHY

The research philosophy for this study involves both pragmatism and interpretivism. Pragmatism involves both qualitative and quantitative research strategies. This study includes multiple methods of data collection using both qualitative and quantitative approaches. The qualitative data collection included observations and interviews, while the quantitative data included a pre-test-post-test design. Since this study was practically testing ideas on learners, and mixed methods were used, pragmatism was appropriate for the research philosophy of this study. Together with pragmatism, interpretivism provided the lens through which the data was ultimately analysed qualitatively, therefore interpretivism was included in the research philosophy of this study. Pragmatism suggests working deductively and/or inductively, while interpretivism suggests working inductively, the former contributing to the study's objectivity, and the latter to subjectivity.

Game playing, through engagement, falls largely under the Social Constructivist Theory. The naturalist (interpretive) paradigm is used when research is done using interviews and observations (Nieuwenhuis, 2007b).

Constructivism is a paradigm that suggests that knowledge is constructed through experience. Moreover, the Social Constructivist Theory includes collaboration, which is measured in this study. These ideas led to the use of collaborative games in this study. One of the assumptions of interpretivism rests in the construction of knowledge through the social world (sharing meanings and interaction).

3.3 METHODOLOGICAL CHOICE

This study concerns the developmental influences of collaborative games in the Grade 6 mathematics classroom. A qualitative approach was used, while research strategies used both qualitative and quantitative methods. Within the quantitative approach, a quasi-experimental design was used for an intervention with Grade 6 learners. A quasi-experimental design required the use of existing groups, therefore it was the ideal approach due to learners already being assigned into four classes. Two classes were assigned as the experimental group, and the other two classes as the comparison group.

The following table summarises the specifics of the research process. The table includes the aim, objectives, research questions, the concepts from the theoretical framework, data sources, and methodology. The concepts from the theoretical framework and data sources are organised next to the relevant sub-questions that they address.

Table 3.1: Research design plan combining elements from the research process

AIM	OBJECTIVES	RESEARCH QUESTION	SUB-QUESTIONS	CONCEPTS FROM THEORETICAL FRAMEWORK	DATA SOURCES	METHODOLOGY
To investigate the developmental influences of collaborative games in the Grade 6 mathematics classroom.	To promote the use of games in the mathematics classroom, to raise awareness in teachers of its positive influences on learner development, and to provide teachers with the knowledge on how to design quality educational games.	How do collaborative games influence learners' development in the Grade 6 mathematics classroom?	How are educational games beneficial to learning and development in mathematics? How does collaboration influence learning and development in mathematics?	Play; Challenges; Fun; Interaction; Engagement; Competition; Practice; Visual; Logical; Mathematical; Computational; Exploration; Discovery; Critical thinking; Goal formation; Goal completion; Short-term memory; Long-term memory.	Literature; Teacher interview; Observations; Intervention results.	Intervention; Observations; Interviews.

3.4 RESEARCH TECHNIQUES AND PROCEDURES

The research techniques and procedures that are described in this section include the selection of participants and sampling procedures, the data collection process, and the instruments that were used to collect and document the data.

3.4.1 Selection of participants and sampling procedures

The participating school was chosen through convenience sampling, which is easy, convenient, quick, and cheap (Maree & Pietersen, 2007b). Non-probability methods do not make use of randomisation, nor do they represent the population, therefore the results cannot be generalised (Maree & Pietersen, 2007b). Purposive sampling was used when choosing the specific grade and teacher from this school. The study focused on mathematics and Grade 6.

A quasi-experimental design consists of two groups, the experimental and comparison group. An intervention was employed where two of the four Grade 6 classes (experimental group) completed a collaborative game-based worksheet, while the other two classes (comparison group) continued working from the textbook. These classes formed the experimental and comparison groups (Ary Jacobs & Razavieh, 2002). For the intervention, the sample size *n* was 51. The experimental group consisted of 28 participants, and the comparison group of 23 participants. The quasi-experimental design was used since randomisation was not possible as learners were already organised into classes (Ary et al., 2002). Although these sampling methods limit the study due to the sample not being a true representation of the population, they were the most appropriate methods to sample participants without it being harmful to them in any way.

The school assigns an alphabet letter to each class in the order: ‘S’, ‘K’, ‘U’, and ‘L’ and the position of the letters in this order was used to assign classes to the experimental or comparison group. The two classes in the first and third position (one and three being uneven numbers), in that order, were assigned to the experimental group. The other two classes in the second and fourth position (two and four being even numbers), in that order, formed the comparison group.

3.4.2 Data collection process

The data collection took place at a primary school. The principal, Grade 6 mathematics teacher, and all of the Grade 6 learners received letters (see Addendum A and B) explaining the study and seeking permission from them to participate in the study. The four Grade 6 classes were assigned to the experimental group or the comparison group (two classes per group). The data collection methods included: intervention, observations, and interviews. Table 3.2 provides detail on the data collection process for the three data collection methods.

The intervention was executed by using a pre-test-post-test design. Four mathematics topics were covered, one topic each week, over a period of four weeks (see Section 3.5.3.1). For each topic, a pre-test and a post-test were completed. Table 3.2 show the pre-tests that were completed at the beginning of a week and the post-tests that were completed on Fridays. The pre-tests were made up of activities from the learners' Grade 5 mathematics textbook (testing pre-knowledge), and the post-tests were made up of the Grade 6 mathematics textbook (testing new knowledge). The learners completed the pre-tests individually in class without revision on the topic. On the Friday, the teacher would teach her class as she normally did, introducing new knowledge, and afterwards the learners would complete the post-test. For the post-tests, the comparison group completed the activity from their textbook, and the experimental group completed the same activity, but in the form of a game-based worksheet. The results of the pre-tests and post-tests were recorded on class lists and transferred to a spreadsheet for analysis .

Observation schedules were completed for each class while they received the lesson, and during the completion of the game-based worksheet/textbook activity. The observation schedule was adapted to be useful for both the experimental and comparison group, therefore the findings can be compared according to differences and similarities. The observation schedule contained

10 main observations that were observed during the intervention, with a 'comments' column in which additional observations could be written. Moreover, a semi-structured interview was scheduled before the intervention period started, and the same interview was scheduled after the four weeks of intervention. The interviews took place in the mathematics teacher's classroom. The questions were structured in a way that extra questions could be added to clarify what the teacher had said or to add ideas to the interview that were not thought of when the questions were designed. The teacher's perspectives and ideas, beliefs, opinions and behaviour were compared from the start of the intervention to when the intervention period was completed. The interviews were transcribed in Afrikaans and translated to English.

The following table provides a timeline for the data collection process, including the mathematics topics and the date, data collection instrument, source, and participant pertaining to the relevant mathematics topic. These can be seen in the first column. In Table 3.2, 'source' refers to either the Grade 5 or the Grade 6 mathematics textbooks, depending on the test (pre-test or post-test) and the group (experimental or comparison) that were used in selecting the questions for both instruments. This study used activities from the "Oxford Suksevolle Wiskunde Graad 5 Leerdersboek" ("Oxford Successful Mathematics Grade 5 Learner's book") and the "Oxford Suksevolle Wiskunde Graad 6 Leerdersboek" ("Oxford Successful Mathematics Grade 6 Learner's book"). By using these two official textbooks in the intervention, which are used by the Grade 5 and 6 learners who participated as part of school every day, this study avoided disrupting the learners' learning process.

Table 3.2: Data collection process

Mathematics topic	**Date (2017)**	**Data collection instrument**	**Textbook activity/Game-based worksheet**	**Participant**
	19 April (Wednesday)	Semi-structured interview.		Mathematics teacher.
Multiplication	19 April (Wednesday)	Pretest 1.	Activity taken from the Grade 5 mathematics textbook.	Comparison and experimental groups.

Mathematics topic	Date (2017)	Data collection instrument	Textbook activity/Game-based worksheet	Participant
	21 April (Friday)	Post-test 1 and observations.	Activity taken from the Grade 6 mathematics textbook.	Comparison group.
			Game-based worksheet.	Experimental group.
Nets of 3D-objects	2 May (Tuesday)	Pre-test 2.	Activity taken from the Grade 5 mathematics textbook.	Comparison and experimental groups.
	5 May (Friday)	Post-test 2 and observations.	Activity taken from the Grade 6 mathematics textbook.	Comparison group.
			Game-based worksheet.	Experimental group.
Symmetry	8 May (Monday)	Pre-test 3.	Activity taken from the Grade 5 mathematics textbook.	Comparison and experimental groups.
	12 May (Friday)	Post-test 3 and observations.	Activity taken from the Grade 6 mathematics textbook.	Comparison group.
			Game-based worksheet.	Experimental group.
Division	15 May (Monday)	Pre-test 4.	Activity taken from the Grade 5 mathematics textbook.	Comparison and experimental groups.
	19 May (Friday)	Post-test 4 and observations.	Activity taken from the Grade 6 mathematics textbook.	Comparison group.
			Game-based worksheet.	Experimental group
	23 June (Friday)	Semi-structured interview.		Mathematics teacher.

3.4.3 Data collection and documentation

In this section, the data collection methods and documentation are discussed in detail. The data collection methods included: intervention, observations, and interviews. The format in which the data is documented is also explained in detail for each data collection method.

3.4.3.1 Intervention

A pre-test-post-test design was used for this study. As explained in the sampling procedures, a quasi-experimental design makes use of existing groups, therefore the four Grade 6 classes were assigned as a whole class either to the experimental group or the comparison group for the intervention period. The four mathematics topics covered during the intervention are: multiplication, nets of 3D-objects, symmetry, and division. Multiplication and division are part of the content area 'numbers, operations, and relationships', which requires skills in the second cognitive level of procedural knowledge (see Chapter 1, Section 1.8). Nets of 3D-objects and symmetry are part of the content area 'space and shape', which requires skills in the first cognitive level of knowledge (see Chapter 1, Section 1.8).

Each of the four chosen mathematics topics were covered in one week. A pre-test and corresponding post-test were completed for every topic. Since there were four mathematics topics, the duration of the intervention period was four weeks. Pre-tests were scheduled to be completed individually in class at the beginning of the week, and post-tests were completed on the Friday. All of the participants completed the same pre-tests (see Addendum C), activities taken from the Grade 5 mathematics textbook (testing pre-knowledge) prescribed by the school. On the Friday, all of the classes received the same lesson and content from their teacher as she would normally teach. Afterwards, the learners completed the post-tests (testing new knowledge). For the post-tests, the comparison group completed the questions from their Grade 6 mathematics textbook (see Addendum D), while the experimental group completed the same questions, but these were designed into game-based worksheets (see Addendum E). Each pre-test and post-test was marked and the results were recorded onto class lists before being anonymously typed into an Excel spreadsheet (see Addendum F) to be able to generate tables and figures for the analysis of results.

The collaborative game-based worksheets were designed using the theoretical framework in designing quality educational games, as explained in Chapter 2. The game-based worksheets' questions that the comparison group completed were taken as is from the activities in the Grade 6 mathematics textbook. Since the activities in the Grade 6 mathematics textbook were designed according to the specifications of the CAPS document, the game-based worksheets were therefore also aligned therewith.

3.4.3.2 Observation schedule

All four Grade 6 classes' participants were observed every Friday during the lesson and completion of the post-test (game-based worksheet/textbook activity). The observation schedules focused on specific predetermined interfaces, which were selected from the GOM (theoretical framework, see Section 2.5). The underlined parts are the main observations on one or more of the interfaces. The interfaces are italicised in the explanations below each observation number:

The observation schedules took note of:

1. Learner's <u>focus when the content is being taught:</u>

   Learners are motivated to learn when educational games are implemented (Chen & Law, 2016). Learners' focus during the teacher's instruction was observed when they knew that they needed the knowledge to be able to complete a game-based worksheet,. When learners focus, their *short-term memory* and *long-term memory* could improve because they are trying to remember the content for future use.

2. Game influence on learners' <u>attitude towards working with peers</u>:

   The level of *interaction/engagement* could show learners' attitude towards working together. In contrast to little interaction, great interaction could show that games elicit an attitude of preference towards working together.

3. Learners' <u>motivation to start</u> with the *game-based worksheet/textbook activity*:

   Collaboration develops stronger motivation to perform tasks (Chen & Law, 2016). Not only was collaboration observed as motivation, but also *fun, visual* and *logical* elements, which were included in the game-based worksheet/textbook activity. When elements of games are included such as crossword puzzles or clues, learners have the opportunity to *explore/discover* when they make mistakes. Learner's eagerness to start and the time it took to start the activities/game-based worksheets were observed.

4. Learners' level of fun while completing the *game-based worksheet/ textbook activity*:

   Fun was observed. Learners comfort and laughter while completing the game-based worksheet/textbook activity were observed as indicators of having fun. *Competition* served as motivation to 'want to' complete the game-based activity because *competition* can be *fun*.

5. Learners' engagement with peers (collaboration):

   In contrast with number 2, for *engagement/interaction*, referred to as collaboration in this study, learners were observed as to whether they engaged/interacted with each other or not.

6. Learners' enjoyment of the *game-based worksheet/textbook activity*:

   Mathematics becomes enjoyable when completing a game-based activity (Ramani et al., 2012). *Play* was observed through their participation in playing the games designed in the game-based worksheets. Enjoyment (*fun*) was compared between the experimental and comparison group as the comparison group did not have a game to 'play'. *Competing* in collaboration (*engagement/*interaction) is sometimes part of games, for example, the game-based worksheet on division designed for the intervention.

7. Learners' enjoyment of *collaborating/working individually*:

   Challenges and *competition*, which require collaboration (*engagement/interaction*), could contribute to learners' enjoyment; this is not included in textbook activities. Therefore, when comparing the experimental and comparison group, one can observe whether collaboration or individual work was enjoyed more.

8. Learners' development of a love of mathematics:

   The teacher's influence on the learners' love of mathematics was observed. *Visual* elements of mathematics could stir up a love for the subject due to learners being able to physically take part in activities or think creatively. *Fun* and *play* could be applied in order for learners to develop a love of mathematics because it is enjoyed. When something is loved, it is appreciated and it thus motivates someone to 'want to' do well instead of 'have to' do well. Giving extra attention, having positive attitudes towards collaboration, and doing what is asked could indicate an appreciation, respect, passion, and love of what mathematics is.

9. Learners' completion of the *game-based worksheet/textbook activity*:

   Goal formation, *goal completion*, *discovery/exploration*, *practice*, and *engagement* with the content were observed during the completion of the game-based worksheet/textbook activity. The way in which learners went about starting, executing and completing it was observed. Whether learners completed the work or not was also observed as an indicator of either collaboration, playing a game, or the content of the work being time consuming.

10. Learners' learning from peers:

    Short-term memory, *long-term memory*, *critical thinking* and *discovery/exploration* were observed. Although it was not possible to determine development in these attributes, the 'aha' moment was observed when learners were able to discover answers by working together when they applied critical thinking.

Observation numbers 2, 5 and 10 did not apply to the comparison group. Observation numbers 3, 4, 6 and 9 used the words 'game-based activity' for the experimental group, and 'textbook activity' for the comparison group, and observation number 9 used the words 'collaborating/working individually'. The above-mentioned observations were ticked with a checkmark on the observation schedule as either 'poor', 'average', or 'excellent'. The relevant observations were written under the 'comments during observation' column next to the appropriate observation. Additional observations and comments provide a better understanding, add to the depth to the study, and include ideas that were not in the original observation schedule. All observation schedules are included as Addendum G.

3.4.3.3 Semi-structured interview

The questions for the semi-structured interview were designed to gain a different perspective on ideas, beliefs, opinions and behaviours. It was important to gain the perspective of someone else that would contribute to answering the research questions. Two semi-structured interviews were held with the Grade 6 mathematics teacher in her classroom. The same interview was used before and after the intervention period to compare whether her ideas, beliefs, opinions or behaviour had changed or stayed the same. The structure of the interviews allowed for extra questions to be asked when uncertainties were experienced, or new ideas arose to be questioned. The data obtained through the interviews would not have been obtained through the observations, and were used to supplement the data obtained during the observations and the results from the intervention.

The interviews were transcribed word for word in Afrikaans, as the teacher answered the questions in Afrikaans. Afterwards, they were translated into English. The transcripts were coded in order to identify the predetermined components and interfaces from the theoretical framework explained in Section 3.5.3.2. The translated transcripts are included in Addendum J and the original transcripts in Afrikaans are available on request.

3.5 QUALITY CRITERIA

It is important for this study to be trustworthy. Trustworthiness is improved through the use of multiple methods. Both a qualitative and quantitative approach were used in collecting, analysing, and interpreting data. Although randomisation was not possible due to the quasi-experimental design used in the intervention phase of this study, some degree of randomisation was implemented and has contributes to the validity of this study. The school used specific alphabet letters in a specific order, namely 6S, 6K, 6U, and 6L. The classes in first and third (one and three being uneven numbers) position, namely S and U, formed the experimental group, and classes in the second and fourth (two and four being even numbers) position, namely K and L, formed the comparison group. Therefore, I was not able to choose the better performing classes for the experimental group, but maintained some degree of randomisation. A computer program randomly assigned learners into new classes each year at the school, which eliminates human influence and contributes to the objectivity of this study.

During the intervention period, the pre-tests and post-tests' results were not influenced because learners completed the pre-test activities in class, based on pre-knowledge and with no revision on the topics. The post-tests were completed on a Friday immediately after the teacher had taught the new content on the topic, therefore there was no extra time for learners to practise beforehand at home. Observations were made from the back of the class and learners were taught by their mathematics teacher, who they were comfortable with as they were used to her way of teaching, therefore observing had little or no influence on the learners' behaviour. This contributes to the objectivity of the study. After the intervention period, the teacher was asked to check whether she agreed or disagreed with what was observed, as well as providing additional observations written in as comments on the observation schedules. Since she was also in the classroom and teaching, she was able to confirm what was observed.

During the interviews, questions or sentences were added to clarify or add to what had been said. The second interview included the same questions as the first, therefore, the teacher could add anything she forgot to say during the first interview. Certain answers had changed from the first interview after she noticed the influence of game-based worksheets on learners' development, meaning she had misperceptions about the incorporation of collaborative games into her classroom until she implemented it herself and saw the results.

3.6 DATA ANALYSIS AND INTERPRETATION

The quantitative data was collected systematically and objectively following a time schedule. The pre-tests and post-tests' results were recorded onto class lists and into an Excel spreadsheet where they were clearly organised for easy analysis. Descriptive statistics were used to organise and summarise the data obtained from the intervention's pre-test-post-test design. The statistical methods used included: double bar graphs, a line graph, and a measure of central tendency (mean). Since this is a qualitative study, the quantitative data, even though analysed statistically, ultimately was interpreted and summarised qualitatively. The quantitative results were thus used to supplement the qualitative findings. Another statistical method was used to document, organise and summarise the findings from the observation. This includes presenting the data in double bar graphs, and in a frequency distribution for each observation. Double bar graphs are used to present the comparisons between the experimental and comparison groups. Summaries were written on the additional observations that were included under the 'comments' column of the observation schedules and used to support the findings of the observed categories.

The interviews were transcribed and a content analysis was used in coding and summarising the data from the transcripts. The transcriptions were coded according to predetermined categories from the theoretical framework that was set out in Section 2.5. A deductive and inductive approach was used to code both predetermined categories and emerging themes. The differences and similarities in codes were then compared from both interviews. The results from the intervention and the findings from the observations and interviews were used to determine whether the data complied or did not comply with the posited theory that collaborative games have a positive influence on Grade 6 learners' development in mathematics.

3.7 Ethical considerations

It is important to consider ethics when conducting any study. The first important issue in conducting this study was to obtain permission from the relevant parties including: the Gauteng Department of Education, the University of Pretoria, the chosen school, the Grade 6 mathematics teacher, and all of the Grade 6 learners participating in the intervention, including the experimental and comparison group. An application for ethical clearance was submitted and approved by the University of Pretoria. Thereafter an application for approval to conduct this study in a school in Gauteng was submitted to the Gauteng Department of Education, and was approved. Letters of consent were given to the principal of the chosen school and to the Grade 6 mathematics teacher that were to be completed and signed in order to participate. The learners received letters of assent and their parents/guardian a letter of consent that were to be completed and signed to agree/disagree to participate.

In the event that the parent/guardian disagreed with their child taking part in the study, the learner continued working from the textbook as they normally would. Learners that did not participate were not disadvantaged because they were completing the same work as the comparison group that completed the activity from their textbook. These learners' marks were not recorded for this study. The participants' identities were kept confidential by giving each learner a number from 1 to 51 on the spreadsheet that included their results. After the completion of the study, the material was stored at the University of Pretoria in the Science, Mathematics and Technology Department. All data collected, including recordings of the interviews, will only be used for academic purposes and will be locked up for safety and confidentiality purposes. All data collected with public funding may be made available in an open repository for public and scientific use.

3.8 SUMMARY

This chapter discussed the research process carried out in this study. The research design plan summarised the research methodology in an organised manner, which made it easy to keep to the focus of the study. The data collection process in Table 3.2 presented a plan to collect data systematically with a clear layout of what needed to be done. The intervention, observations and interviews were described in detail. Quality criteria was discussed in terms of the trustworthiness of the study. Ethical considerations were also included to provide the steps that were taken in conducting an ethically sound study. In the next chapter, the data will be analysed and interpreted into the findings as these will answer the research questions posed in this study.

CHAPTER 4 RESEARCH RESULTS AND FINDINGS

4.1 INTRODUCTION

This chapter aims to provide the research findings/results pertaining to the research questions posed in this study. A description of the participants provided context for the presentation and analysis of the data, while the theoretical framework provided the categories that were used to code and interpret the observations and interviews. The data is presented in the following order: intervention, observations and interviews. Visual presentations of the data from these three data collection methods are provided in the form of tables and graphs. The observations and interviews were coded in an attempt to answer the research questions, while the analysis and interpretation of the intervention results were used to support the descriptions of each code.

The following table provides the data collection, including the specific observation number/interview question number that was connected to the predetermined components (objects) and interfaces of an educational game design (used as codes) based on the theoretical framework. The four game-based worksheets used during the intervention are not included as a data collection method in Table 4.1 below, but the game-based worksheets were designed with these components (objects) and their abstract/concrete interfaces. Therefore, the end results from the intervention are a reflection of a combination of these components.

Table 4.1: Data collection for the predetermined components and interfaces of an educational game design

Component (Object)	Code (Abstract/concrete Interfaces)	Data Collection	
		Observation number(s)	Interview question number(s)
GAME SPACE	Play	6 and 8	2, 3, 4, 5, and 6
	Exploration	3, 9 and 10	2, 6, 7, and 9
	Challenges	7	8
	Engagement	2, 5, 6, 7 and 9	1, 3, 4, 6, and 9

Component (Object)	Code (Abstract/concrete Interfaces)	Data Collection	
		Observation number(s)	Interview question number(s)
VISUALISATION SPACE	Critical thinking	10	2, 6, 7, and 9
	Discovery	3, 9 and 10	2, 6, 7, and 9
	Goal formation	9	2, 3, 5, and 6
	Goal completion	9	2, 3, 5, and 6
	Competition	4, 6, 7 and 9	2, 5
	Practice	9	3, 6
ELEMENT SPACE	Fun	3, 4, 6 and 8	1, 2, 6, 7, and 9
ACTOR SPACE	Interaction	2, 5, 6 and 7	1, 3, and 4
PROBLEM SPACE	Visual	3 and 8	8
	Logical	3	8
	Mathematical	-	4, 8, and 9
	Computational	-	3
	Short-term memory	1 and 10	5, 7, 8, and 9
	Long-term memory	1 and 10	5, 7, 8, and 9

4.2 THE PARTICIPANTS

This section includes the participants' biographical information. The teacher's name is not used and she is referred to as 'mathematics teacher' to protect her identity. The Grade 6 learners were assigned a number (1 to 51) for the recording of their pre-test and post-test results, which respected their anonymity.

4.2.1 Mathematics teacher

Purposive sampling was used to choose the Grade 6 mathematics teacher due to the study focusing on mathematics and Grade 6. The mathematics teacher was female and the only participant in the semi-structured interviews. Her highest qualification was a Baccalaureus Primae Educationis (Senior Primary), with 18 full years of experience as a teacher. At the time of this study she was a Grade 6 mathematics teacher.

The mathematics teacher facilitated the intervention of this study in her class by teaching her classes as she usually would if there were no study involved, by either implementing the game-based worksheets with the experimental group or continuing working from the textbook with the comparison group.

4.2.2 Grade 6 learners

According to the school's standards, Grade 6 learners' average should lie between 63% and 66%. The Grade 6 learners' grade average for mathematics was 66% in Term 1 before the intervention took place in Term 2, which falls into the standard category. The Grade 6 learners were chosen from the participating school through purposive sampling for the purpose of this study. These learners' ages varied between 11-12 years. All of the Grade 6 learners (116 learners) received letters of assent in which they indicated that they agreed/disagreed to take part in the study, as well as a letter of consent to the learners' parent/guardian to be signed in agreement/disagreement for the learner to participate. Out of 116 learners, 51 learners and their parent/guardian completed the forms in agreement to participate in the study. Therefore, the sample size *n* for the intervention was 51, which included 17 males and 34 female participants.

The quasi-experimental design used for the intervention period required an experimental group and a comparison group, and the four classes were divided into these two groups according to the order of their class symbol (explained in Chapter 3, Section 3.4.1). Out of the sample of 51 participants, the experimental group consisted of 28 participants (participant numbers 1 to 28), including 10 males and 18 female participants. The comparison group consisted of 23 participants (participant numbers 29 to 51), including 7 males and 16 female participants. All of the participants were required to complete a pre-test and post-test on four different mathematics topics.

4.3 CODING OF THE DATA

The theoretical framework provided the predetermined (*a priori*) codes that were used to code the findings from the observation schedules and the transcripts of the interviews. These codes (interfaces) are: play, exploration, challenges, engagement, critical thinking, discovery, goal formation, goal completion, competition, practice, fun, interaction, visual, logical, mathematical, computational, short-term memory and long-term memory. The intervention results were written onto class lists and later typed into an Excel spreadsheet (see Addendum F). These results are presented in tables and graphs in Section 4.4 with their interpretations. Specific observations were ticked off during the intervention and also typed into a different Excel spreadsheet (see Addendum G) in order to generate tables and graphs. The interviews were transcribed word for word in Afrikaans, and afterwards translated into English (see Addendum J), and the teacher's answers summarised in table format. While the observation schedules aimed to observe the interfaces, as selected from the theoretical framework under the main observation categories, the data from the interviews were coded according to these interfaces. Interpretations are provided for each table and figure presented in Sections 4.4 - 4.6.

4.4 INTERVENTION

The pre-test-post-test design used in the intervention provided quantitative data, which were used to support the qualitative findings from the observations and interviews. The data gathered provided information regarding learners' achievement in mathematics in four different mathematics topics: multiplication, nets of 3D-objects, symmetry, and division. These four topics fall under specific content areas in the CAPS document. The content area 'space and shape' covers nets of 3D-objects and symmetry, and 'numbers, operations, and relationships' covers multiplication and division.

As mentioned in Chapter 1, it was posited that the implementation of collaborative game-based worksheets would increase learners' development in mathematics and as a result, have a positive influence on their achievement in mathematics. The theoretical framework includes components (made up of interfaces) of educational games that were used to design the game-based worksheets for the intervention. These later functioned as the codes used to analyse the observations and interviews. Since the game-based worksheets were designed using the components and interfaces of educational game design, the results from the game-based worksheets are a reflection of these interfaces. Therefore, the contributions from the components and their interfaces to learners' development in mathematics can be said to have led to learners' higher achievement in mathematics. The results are presented in the following three sections including: a summary of the intervention results, a comparison of the pre-test results and post-test results, and a comparison of the experimental group and comparison group.

4.4.1 Summary of the intervention results (pre-test-post-test design)

The data gathered from the intervention were transferred from class lists to an Excel spreadsheet, which made it possible to analyse the data using formulas and graphs. A complete list of all of the participants' individual pre-test and post-test results on all four topics is provided as Addendum F, and summarised in the following table.

Table 4.2: Summary of the intervention results (pre-test-post-test design)

INTERVENTION RESULTS DOCUMENTED DURING PRETEST AND POSTTEST												
TOPIC		MULTIPLICATION		NETS OF 3D-OBJECTS		SYMMETRY		DIVISION		TOTAL PRETEST AVERAGE	TOTAL POSTTEST AVERAGE	DIFFERENCE BETWEEN PRE AND POST
DATE		19 APRIL	21 APRIL	2 MAY	5 MAY	8 MAY	12 MAY	15 MAY	19 MAY			
PRE/POST		PRE	POST	PRE	POST	PRE	POST	PRE	POST			
TOTAL		6	6	4	6	21	14	4	4			
EXPERIMENTAL GROUP	AVERAGE	3,63	4,80	3,92	5,93	15,44	11,85	2,89	3,86			
	PERCENTAGE	60,49	80,00	98,08	98,77	73,52	84,62	72,32	96,43	76,10	89,95	13,85
COMPARISON GROUP	AVERAGE	3,91	4,22	3,71	5,90	15,64	12,45	2,65	3,18			
	PERCENTAGE	65,22	70,29	92,86	98,33	74,46	88,96	66,30	79,55	74,71	84,28	9,57
DIFFERENCE BETWEEN EXPERIMENTAL AND COMPARISON GROUP		-4,72	9,71	5,22	0,43	-0,94	-4,35	6,02	16,88	1,39	5,67	4,28
ABSOLUTE DIFFERENCE		4,72	9,71	5,22	0,43	0,94	4,35	6,02	16,88	1,39	5,67	4,28

The top headings provide the following: the four different mathematics topics, the date of completion, pre-test or post-test, and the total marks for each. The pre-tests and post-tests each consist of different totals, therefore an average was calculated for each using the Excel formula: '=average'. The average for each was further processed to a percentage using the formula 'average/total*100' in order to be able to compare the results. These average percentages are presented as graphs in Figure 4.1 and Figure 4.2. The headings in the left column are the averages and percentages for both the experimental group and comparison group respectively.

The two bottom rows give the difference between the experimental and comparison group's percentages for each pre-test and post-test under every mathematics topic. The differences were calculated by taking the 'experimental group's percentage minus comparison group's percentage'. Therefore, a negative difference in the second last row indicates that the experimental group had a lower average percentage than the comparison group, and a positive difference indicates that the experimental group had a higher average than the comparison group. The absolute difference between two numbers n_1 and n_2 is $|n_1 - n_2|$, where n_1 is the experimental group and n_2 is the comparison group. The minus sign denotes subtraction and the two vertical bars (absolute value bars) denote absolute value, which is a value equal to or greater than 0. The values are included in the interpretations under Figure 4.1 and Figure 4.2 in Section 4.4.1.

The comparison group's pre-test score on symmetry was 0,94% higher than the experimental group's, as well as a 4,35% higher post-test score. The experimental group scored higher average percentages on three out of the four topics, namely: multiplication, nets of 3D-objects, and division. Out of these three topics, multiplication is the only topic where the experimental group started with a lower pre-test average percentage than the comparison group, and achieved a higher post-test average percentage. The experimental group increased a total of 19,51% in multiplication, of which 4,72% was below the comparison group's pre-test average percentage, and 9,71% above the comparison group's post-test average percentage. Further increases between pre-test and post-test average percentages are given in Table 4.3 following the interpretation of Table 4.2.

The average percentage of the four pre-tests was calculated using the formula: '(pre-test 1 percentage + pre-test 2 percentage + pre-test 3 percentage + pre-test 4 percentage)/4. The average percentage of the four post-tests was calculated using the same formula, but using the four post-tests' percentages. The calculated differences between the experimental group and comparison group are given at the bottom of the table. These revealed that the experimental group scored 1.39% higher in the four pre-tests, and 5.67% higher in the four post-tests. This is further presented in a line graph in Figure 4.3 where both groups' scores from the pre-test and post-test are given. Both groups' respective differences between the pre-test average's percentage and the post-test average's percentage were calculated using the formula: 'total post-test average minus total pre-test average'. It can be seen that in terms of the difference in the total of the four pre-tests and four post-tests' averages, the experimental group increased by 13.85%, and the comparison group by 9.57%. This shows that the experimental group increased by 4.28% (13.85 – 9.57) more than the comparison group. The average values given in Table 4.2 are presented below in Table 4.3, as well as the differences between the four topics' pre-test and post-test averages for each group respectively. By looking at each group's results individually, one can determine if the collaborative game-based worksheets influenced the experimental group's achievement, and whether the textbook activities influenced the comparison group's achievement in each topic.

Table 4.3: Differences between the pre-tests and post-tests' average percentages for the experimental group and comparison group

Differences between pretests and posttests' average percentages						
		Pretest	Posttest	Difference between pretest and posttest	Increase/ Decrease	Average increase
Experimental group	Multiplication	60,49	80,00	19,51	Increase	13,85
	Nets of 3D-objects	98,08	98,77	0,69	Increase	
	Symmetry	73,52	84,62	11,09	Increase	
	Division	72,32	96,43	24,11	Increase	
Comparison group	Multiplication	65,22	70,29	5,07	Increase	9,57
	Nets of 3D-objects	92,86	98,33	5,48	Increase	
	Symmetry	74,46	88,96	14,50	Increase	
	Division	66,30	79,55	13,24	Increase	

The values presented in Table 4.3 are visually presented in Figure 4.4 and Figure 4.5, and are included in the discussions of each figure. The differences between the pre-tests and post-tests were calculated: Post-test−pre-test. All the differences are positive and indicated as an 'increase' in the 'increase/decrease' column, which means that both groups achieved higher average percentages in every topic, whether it was achieved through completing game-based worksheets or textbook activities. The experimental group's average increase was 13.85%, and the comparison group's average increase was 9.57%, which means that the experimental group scored an average increase of 4.28% more than their comparison group counterparts.

The experimental group improved the most in the topic of division (24.11%), the second most in multiplication (19.51%), the third most in symmetry (11.09%), and the least in nets of 3D-objects (0.69%). The comparison group's increases are presented in the order from most to least: symmetry (14.5%), division (13.24%), nets of 3D-objects 5.48%), and lastly multiplication (5.07%). When considering the two groups separately, the experimental group's two highest post-test average percentages were in multiplication and division (content area 'numbers, operations, and relationships'), while the comparison group's two highest average percentages were in nets of 3D-objects and symmetry (content area 'space and shape'). The experimental group's largest improvements were in multiplication and division. However, when considering both groups' pre-test and post-test average percentages the largest improvements overall were seen in these topics. In comparing the two groups based on their post-test average percentages, the experimental group scored higher in three out of the four topics.

4.4.2 Comparison of the pre-test-post-test results

The values provided by Table 4.2 are used in the presentations below to give greater insight into the figures presented in this section. Comparisons are drawn between the experimental group and comparison group, including their pre-test and post-test average percentages for the four mathematics topics.

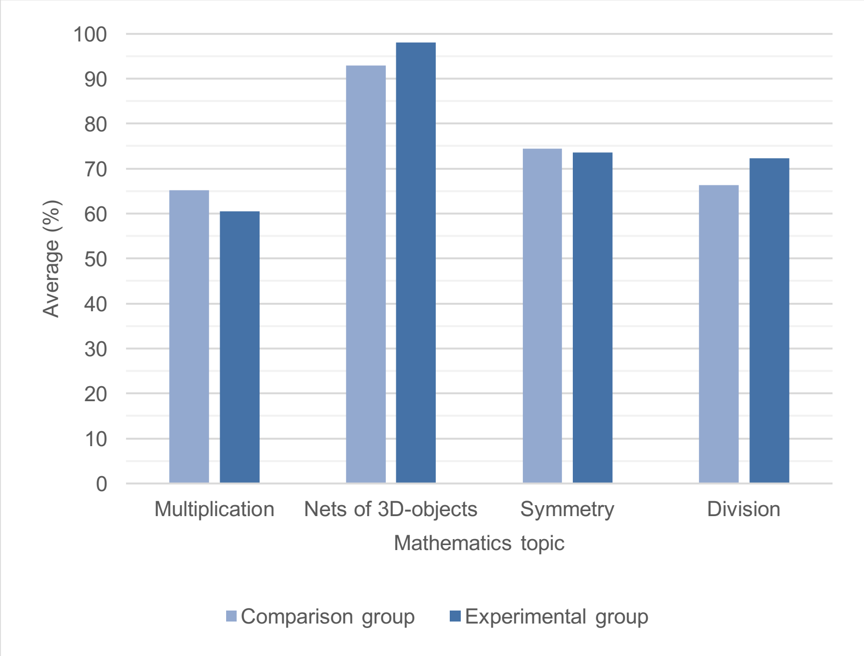

Figure 4.1: Comparison of the pre-test average percentages of the experimental group and comparison group

The bar graph in Figure 4.1 presents a comparison of both groups' pre-test average percentages in the four mathematics topics. The experimental group scored higher pre-test average percentages in nets of 3D-objects (5.22%) and division (6.02%), while the comparison group achieved higher pre-test average percentages in multiplication (4.72%) and symmetry (0.94%). The percentages given in brackets are the differences in pre-test results between the two groups.

Considering the pre-test average percentages, both groups' highest pre-test average percentage was in nets of 3D-objects. The second highest pre-test average percentage for both groups was in symmetry. Nets of 3D-objects and symmetry fall under the content area 'space and shape', which seems to indicate that learners fare better academically in this content area. In contrast with the highest scores, the comparison group scored the lowest pre-test average percentage in division, and the experimental group in multiplication. The participants can be seen as equivalents since the comparison and experimental group completed the same pre-tests in the same formats, their highest scores were in the same topics (nets of 3D-objects and symmetry), and their lowest scores were in the same topics (multiplication and division). The following figure presents a bar graph of the post-test average percentages.

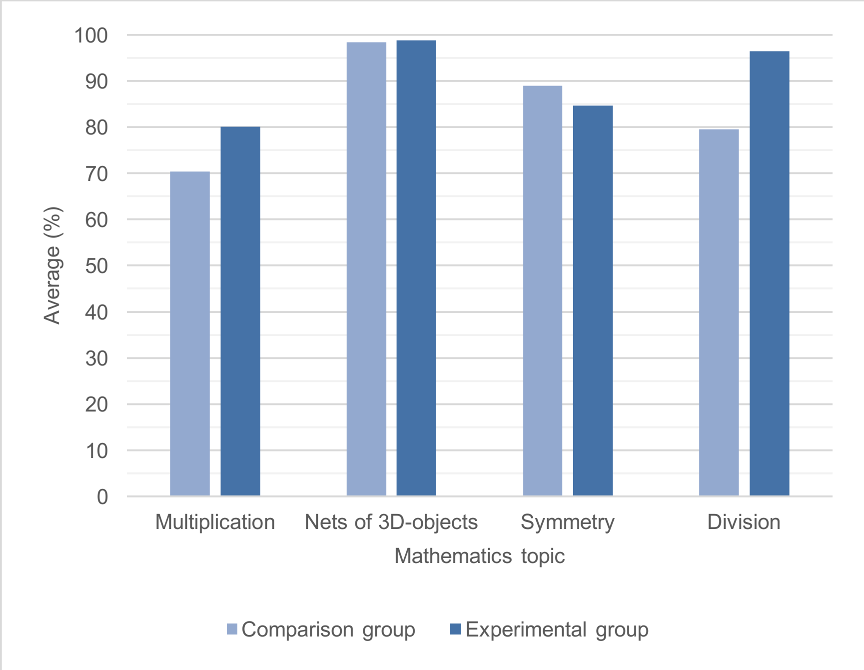

Figure 4.2: Comparison of the post-test average percentages between the experimental group and comparison group

It can be seen that the experimental group's pre-test averages in Figure 4.1 were the higher average percentages in two topics (nets of 3D-objects and division). Alternatively, the experimental group's post-test average percentages were higher in three of the four mathematics topics. That means that the comparison group only scored higher in one of the topics.

The experimental group scored higher post-test average percentages in the same topics that they scored higher on in the pre-tests, with the addition of multiplication. The difference in higher percentage in these three topics isgiven in brackets and includes: multiplication (9.71%), nets of 3D-objects (0.43%), and division (16.88%). The comparison group scored 4.35% higher in symmetry than the experimental group. Comparing the difference in post-test average percentages in each topic, division shows the biggest difference of 16.88% between the two groups. The second biggest difference (9.71%) can be seen in the two groups' post-test average percentage in multiplication. Both division and multiplication fall under the content area 'numbers, operations and relationships', which may indicate that collaborative game-based worksheets had the greatest influence on this content area, which requires procedural work.

The following figure presents a line graph based on the statistics from the last two columns of Table 4.2. It visually presents the respective differences between the experimental and comparison groups' pre-test and post-test average percentages.

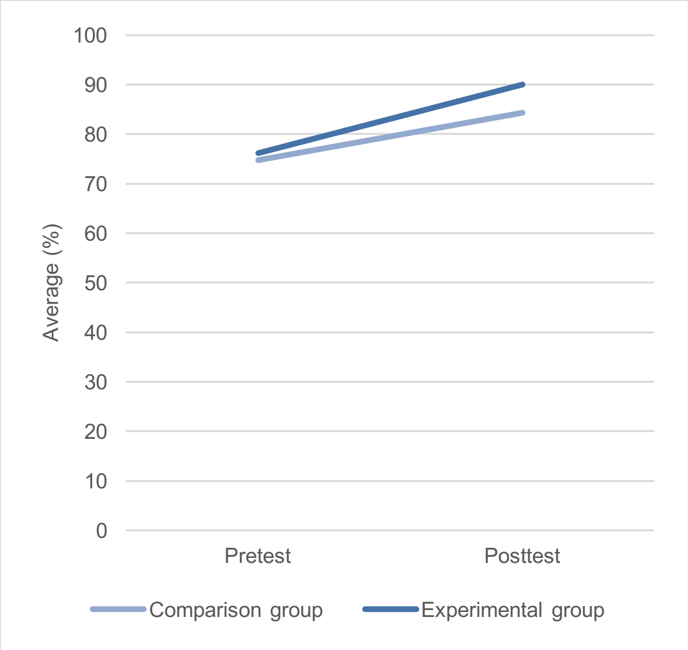

Figure 4.3: Overall pre-test and post-test average percentages between the experimental group and comparison group

It can be seen in Figure 4.3 that the experimental group's pre-test average percentage was 1.39% higher than that of the comparison group. After the intervention, the experimental group's average percentage was 5.67% higher than that of the comparison group. To determine the expected post-test average percentage for the experimental group, 1.39% can be added to the comparison group's post-test average percentage of 84.28%, which means that the experimental group should have scored 85.67% (84.28% + 1.39%) in the post-test average percentage if they had also completed the textbook activities. Instead, the experimental group scored 89.95% in the post-test average percentage, which is 4.28% (89.95% – 85.67%) higher than the expected outcome, which resulted from the implementation of the collaborative game-based worksheets.

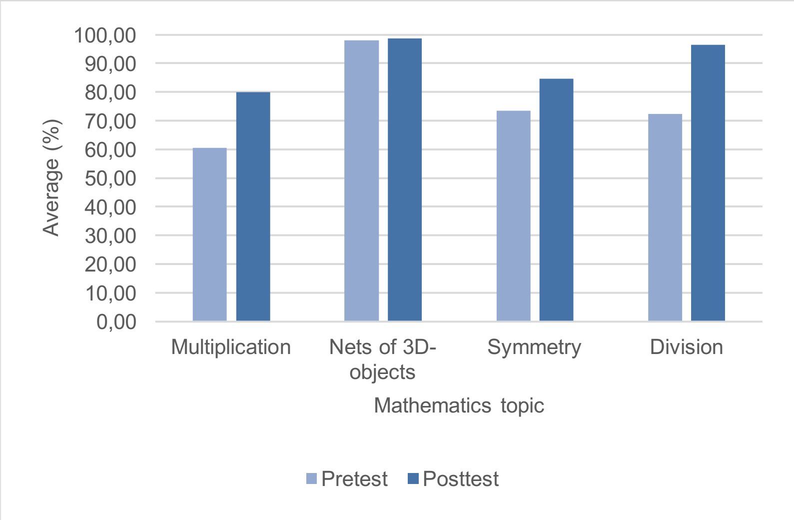

Figure 4.4: Comparison of the experimental group's difference in pre-test and post-test average percentages

It can be seen that the average increase for the four topics was 13.85%, as mentioned in the discussion of Table 4.3. The greatest increase between the pre-test and post-test average percentages was in division (24.11%). The second highest increase was in multiplication (19.51%), while the smallest increase was seen in the topic of nets of 3D-objects (0.97%). This could indicate that collaborative game-based worksheets do not influence academic performance in the content area 'space and shape'. Alternatively, collaborative game-based worksheets showed positive influences on the content area 'numbers, operations and relationships'.

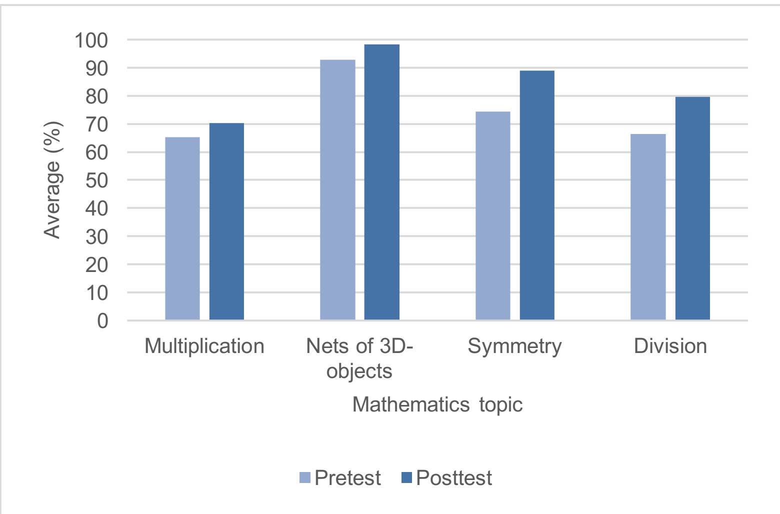

Figure 4.5: Comparison of the comparison group's differences in pre-test and post-test average percentages

Figure 4.5 presents the comparison group's pre-test and post-test average percentages. The comparison group scored the highest increase of 14.5% in symmetry in their average percentage between the pre-test and post-test. The second highest increase was in division at 13.24%. The increase between the pre-test and post-test in multiplication was 5.07%, and 5.48% in nets of 3D-objects, which is similar. The comparison group's results show more consistent increases and less extreme values. Since the comparison group worked from their textbooks and still managed to score higher in every post-test than its corresponding pre-test, it indicates that learning took place.

4.5 OBSERVATIONS

As explained in Chapter 3, the same observation schedule was used for the experimental and the comparison group alternating between a game-based worksheet and textbook activity, and between collaborating and working individually. These words are italicised on the observation schedules (see Addendum G) to indicate one or the other, depending on the group that was being observed. The experimental group were observed using the words 'game-based worksheet' and 'collaborating' on the observation schedule. The comparison group was observed using the other words relating to their situation, including 'textbook activity' and 'individually'.

The comparison group was not observed for observation numbers 2, 5, and 10, therefore 'N/A' (not applicable) is used on the observation schedule. These three observations pertain only to the experimental group and are discussed at the end of this section. Although the comparison group was not observed for these three observations, comments were made and their relevance to these observations were also included in the discussion of the experimental group.

The 10 main observations on the observation schedules (See Addendum G) were ticked off as either 'poor', 'average', or 'excellent', and include additional observations in the 'comments' column. The discussions of the 10 main observations include the predetermined interfaces (codes) of educational games identified in the theoretical framework, which are italicised in the discussions of each in Section 5.4.2 and Section 5.4.3.

A total of 32 observation schedules' data were recorded on an Excel spreadsheet in table format (see Addendum H), including every class's observation schedule on each of the four topics. The following table summarises the data provided (see Addendum H) as a frequency distribution of all observations.

Table 4.4: Summarised frequency distribution for each observation

OBSERVATION NUMBER	EXPERIMENTAL GROUP				COMPARISON GROUP			
	POOR	AVERAGE	EXCELLENT	TOTAL	POOR	AVERAGE	EXCELLENT	TOTAL
1	0	0	8		0	2	6	
2	0	2	6		N/A			
3	0	0	8		0	8	0	
4	0	0	8		2	6	0	
5	0	2	6		N/A			
6	0	0	8		0	8	0	
7	0	1	7		0	7	1	
8	0	0	8		0	3	5	
9	0	0	8		0	2	6	
10	0	2	6		N/A			
TOTAL	**0**	**7**	**73**	**80**	**2**	**36**	**18**	**56**
PERCENTAGE	**0,00**	**8,75**	**91,25**	**100**	**3,57**	**64,29**	**32,14**	**100**

Table 4.4 presents a summary of each group's data from their eight observation schedules' respectively. The top row of headings include the observation numbers, the experimental group, the comparison group, and the scale measures used for each group, which were 'poor', 'average', and 'excellent'. The first column provides the 10 main observations from the observation schedule in numeral format. Each group was observed a total of eight times during the intervention period (two classes per group plus four topics equals eight observation opportunities per group). Therefore the total that each observation number could be observed as 'poor', 'average', or 'excellent' was eight times. This is further presented in Figure 4.6 and Figure 4.7 respectively. The three main observations pertaining only to the experimental group are discussed separately in Section 4.5.3. The experimental group's data in Table 4.4 shows that four out of the 10 main observations (observation numbers 1, 3, 6, and 9) were measured eight out of eight times as 'excellent'.

4.5.1 Comparison of the experimental group and comparison group

The comparison group showed frequencies of all three measures, whereas the experimental group only showed frequencies of 'average' and 'excellent'. The following two figures present the experimental and the comparison group's summarised frequencies on each scale, presented in separate pie graphs.

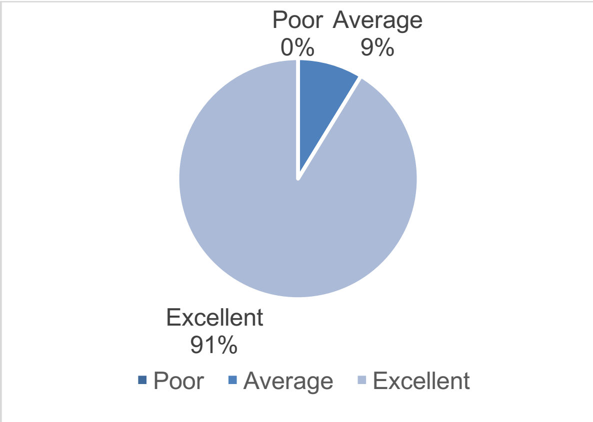

Figure 4.6: Summary of the observations of the experimental group

Figure 4.6 shows the data from the experimental group's eight observation schedules where the participants were observed as scoring 91% 'excellent', 9% 'average', and 0% 'poor'. Since games are not part of the curriculum or class routine, learners got to experience the incorporation of collaborative game-based worksheets as different and fun, which may have influenced them to participate and work at an 'excellent' level.

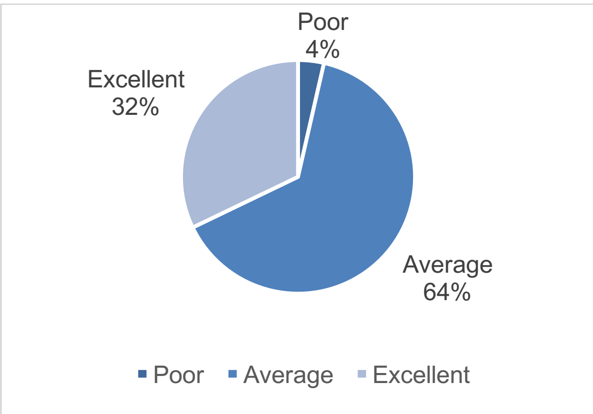

Figure 4.7: Summary of the observations of the comparison group

Figure 4.7 presents the combination of the comparison group's frequencies. Compared to the experimental group's highest frequency being 'excellent', the comparison group's highest frequency observed was 'average' (64%). 'Excellent' was observed 32% of the time, and 'poor' 4%. Although the comparison group completed activities from their textbooks, they were observed a total of 96% times achieving in the 'average' and 'excellent categories'. Since the textbook is used routinely at school, and the learners managed to be observed at 96% in the 'average' and 'excellent' categories, this could indicate that routine does not put learners at a disadvantage. The other reason could be that it is not a necessity to incorporate games into the classroom.

4.5.2 Comparison of the observations

Both group's main observation numbers (1, 3, 4, 6, 7, 8, and 9) on the observation schedules are presented and discussed under Figure 4.8 to 4.14 in the attempt to compare and understand the summarised frequencies provided in Table 4.4. These figures include all the data collected from observing both groups during the intervention period on the four mathematics topics.

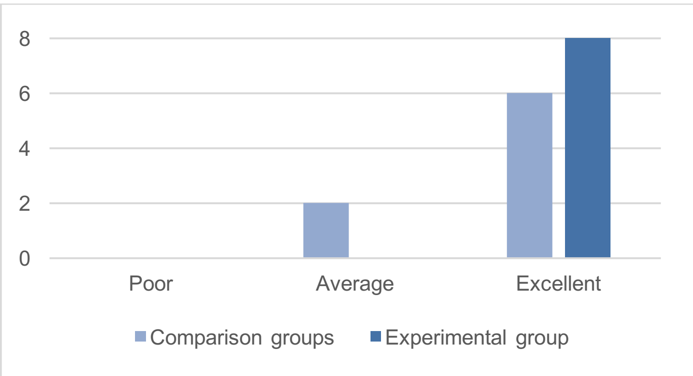

Figure 4.8: Learners' focus when the content is being taught (observation 1)

As shown in Figure 4.8, learners from the experimental group's focus was measured only in the 'excellent' category for each mathematics topic, where the comparison group had a total of six and two in the 'average' category. The fun element of the game-based worksheets could have led to the participants in the experimental group focusing better, which may have led to the experimental group's high average percentages revealed in the summary of the results.

Learners use their *short-term memory* and *long-term memory* to remember information and be able to apply it in the near or far future. Although a game-based worksheet may have caused the learners to focus better in order to play the game, the teacher played an important role in getting the learners' attention and keeping their focus on the content. The mathematics teacher who taught all the classes for the intervention was well prepared, she asked questions, engaged the learners in active learning. This meant that the learners were attentive, eager to answer, and practised examples on their individual A4 sized whiteboards. With or without the implementation of a game-based worksheet, the teacher was experienced, prepared, and put the effort in to keep the learners' focus as she normally would.

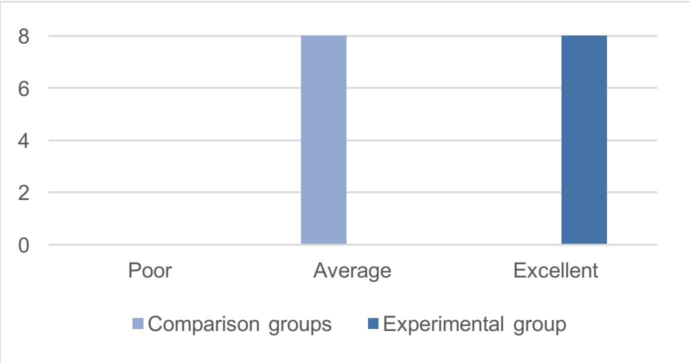

Figure 4.9: Learners' motivation to start with the *game-based worksheet/textbook activity* (observation 3)

The comparison group was observed all eight times as scoring 'average', while the experimental group was observed eight times as scoring 'excellent'. Elements from the theoretical framework were designed into the game-based worksheets, some of which included *fun*, *visual* and *logical* elements. When the teacher introduced the game-based worksheet to the experimental group, their first reaction was yelling out "yes". When the teacher handed the game-based worksheets out, the learners immediately started to cut the worksheet out and paste it into their workbooks. They also signaled to their peers (who they were grouped with) to sit by them. With excitement, some learners said to themselves "1, 2, 3, start". On the multiplication and division game-based worksheets, they showed an attitude of willingness to correct themselves by using the clues in the game-based worksheets (*discovery/exploration*). They also eagerly checked their answers on one of the game-based worksheets, which was hidden as a code behind the teacher's blackboard.

In contrast, learners from the comparison group completed the textbook activities as part of their everyday routine. Their behaviour seemed automated in opening their textbook, looking for the page number, and answering every question. Some learners would start talking to each other instead of completing the activity. It took some learners a bit of time to get started and the teacher had to clap her hands sometimes and say, “Let’s begin”. It also took learners from the comparison group longer to gain momentum once they had started.

The game-based worksheets were designed to be only one A4 page with a clear presentation of what the worksheet was about and how to complete it. The worksheets only contained a few questions, which allowed learners to only see those questions and not get confused or overwhelmed. Unlike the experimental group, the comparison group completed the same questions, but in the form of lists, for example, out of 20 questions, only four numbers were selected for learners to complete. Therefore, the *visual* and *logical* aspect of the game-based worksheets may have contributed to learners wanting to start and complete the worksheet while having fun.

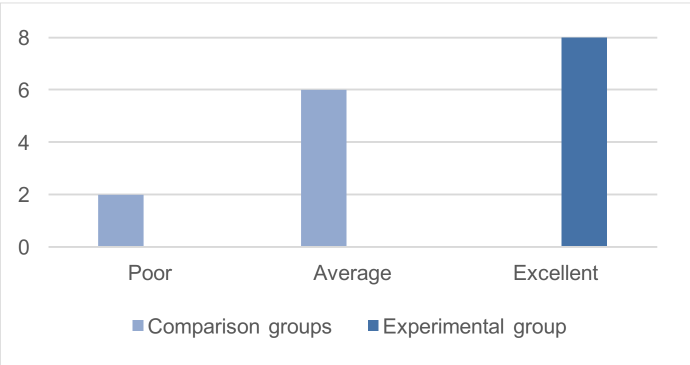

Figure 4.10: Learners’ level of fun while completing the *game-based worksheets/textbook activity* (observation 4)

The experimental group’s level of fun was measured as being ‘excellent’ while completing the collaborative game-based worksheets, while the comparison group was measured to mostly be ‘average’. Therefore, the experimental group had more fun than the comparison group, which may be due to the incorporation of the collaborative game-based worksheets.

One of the additional observations noted, was that the topic of nets of 3D-objects seemed to be *fun* on its own. This could be due to the content area 'space and shape' including pictures, looking easy to do, and excluding procedural operations. Learners from the experimental group seemed eager to listen to the instructions of the game-based worksheets in order to *play* it and have *fun*. When *competition* was brought in with the collaborative game-based worksheet on division, the learners seemed to want to compete because they knew that they were competing in teams of two.

The comparison group's textbook activities on multiplication and division included lists of sums. The learners were required to complete only a few of the sums, but this could be overwhelming for learners in seeing, for example, 20 sums even though they only had four or six sums to complete. Routine is familiar to learners because they know what is expected of them. The learners appeared to be neutral about the work. One learner made a comment that when the method is understood, it becomes *fun*. Therefore, the collaborative game-based worksheets could not be considered as the only source of *fun*.

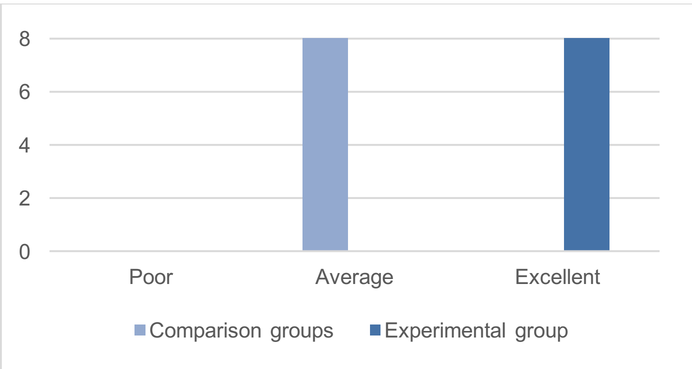

Figure 4.11: Learners' enjoyment of the game-based worksheet/textbook activity (observation 6)

Learners from the experimental group seemed to have more *fun* and enjoy completing a game-based worksheet instead of working from their textbooks. For the worksheet on symmetry, the answers formed a code that was hidden behind the blackboard; the learners enjoyed the secret that they had to find, which seemed more like *playing* a collaborative game (*interaction/engagement*) instead of completing an activity. The *fun* elements made the game-based worksheets enjoyable. Moreover, the learners enjoyed forming teams of two against each other for the *competition* element of the worksheet on division.

The comparison group completed the textbook activities, which looked similar to other activities in the textbook, therefore the learners knew what to expect, which may have added to a sense of familiarity instead of dealing with the unknown (game-based worksheets), which could have been more *fun* and enjoyable. The textbook activities did not include games that could be enjoyed by *playing* or competing against each other. Some activities did not appear enjoyable, for example, multiplication and division, which consisted of lists of sums. Although other activities on topics such as nets of 3D-objects and symmetry were visually stimulating, the enjoyment of completing the activities was measured to be 'average'.

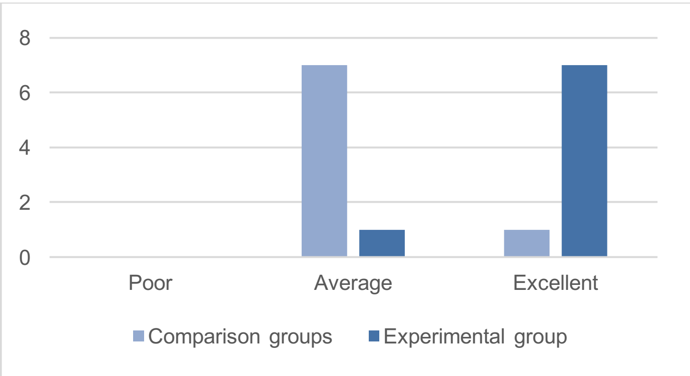

Figure 4.12: Learners' enjoyment of *collaborating/working individually* (observation 7)

Figure 4.12 shows that the comparison group was mostly observed as being 'average' in their enjoyment of working individually, and once as being 'excellent'. In contrast, the experimental group was observed mostly to fall into the 'excellent' category in their enjoyment of working collaboratively. This could mean that the comparison group neither liked nor disliked working individually, which may be due to learners being familiar with working individually.

The experimental group showed a high level of collaboration (*engagement/interaction*). The additional observations written under comments on the observation schedules included that by the third Friday of the intervention period, the learners collaborated more confidently and were more comfortable with collaborating since a level of trust and support had been built between the pairs of learners. With the addition of *competition* to the last game-based worksheet on division, learners were eager to compete collaboratively since they had each other as support structures, which resulted from their relationship being built from the beginning of the intervention.

Alternatively, during the observations of the comparison group, some learners seemed to enjoy working individually and as if they preferred it that way. Additional observations made of the comparison group included learners asking the teacher frequently for help when they struggled. The class tables were arranged in groups and the teacher appointed a group leader to help struggling learners from their group unless it interfered his/her progress. Thus, even though the instructions were that learners work individually, the teacher and group leader were there for support, which meant that struggling learners received the needed support when *challenges* arose, and when they were unable to understand and complete all of the work on their own. Since the struggling learners received help, collaboration had taken place in some form whether it be with the group leader or the teacher. Some learners enjoyed working individually when performing procedures in multiplication and division. A reason for this could be that some learners concentrate better when doing routine procedures.

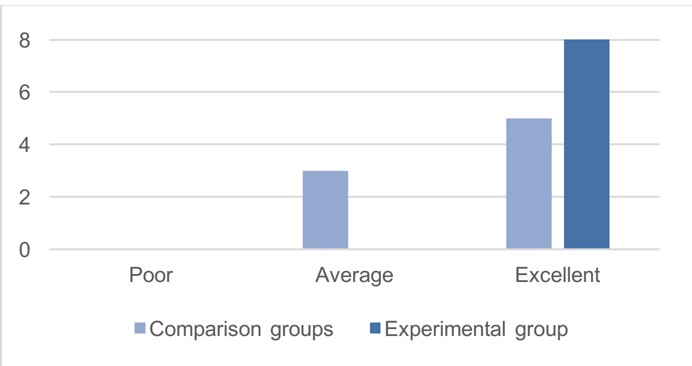

Figure 4.13: Learners' development of a love of mathematics (observation 8)

Loving something includes having good feelings towards it. Learners in the experimental class showed feelings of excitement, *fun*, enjoyment, motivation and enthusiasm. When *play* is introduced, additional feelings like learners *wanting* to work instead of *having* to work were noted during the observations on the experimental group. Nets of 3D-objects and symmetry seemed easy to enjoy due to their *visual* elements. This could mean that learners from the experimental group may have enjoyed these two topics, with or without a game-based worksheet. These two topics may be one of the reasons for the comparison group being observed as ‘excellent’ five out of eight times. Another possible reason could be the mathematics teacher, who created a comfortable space in which learners could learn and develop. Feelings of comfort were observed, which is also relevant to observation number 5, to be discussed in the following section.

The comparison group did not seem excited about the textbook activities, for example, even though nets of 3D-objects are visual and easier to grasp due to physical shapes being used to analyse a 3D-object and *discover/explore*, the textbook activity remains routine. Although, nets of 3D-objects and symmetry could naturally bring about a love of mathematics in learners because it consists of easier concepts and knowledge-based questions. In addition to the game-based worksheets, the teacher seemed to be great at stirring up a love for mathematics in learners through living out her passion for the subject.

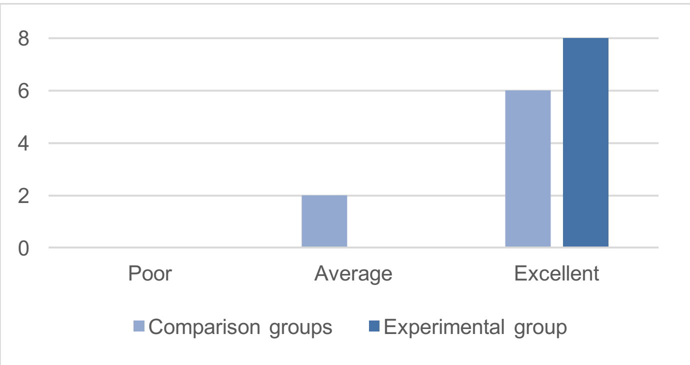

Figure 4.14: Learners’ completion of the *game-based worksheet/textbook activity* (observation 9)

The results show ‘excellent’ completion of the game-based worksheets and textbook activities from the experimental and comparison groups, with the comparison group also observed twice as being ‘average’. Their quick completion of the game-based worksheets may be due to focusing better since they knew they needed to be able to do the work in order to participate in the game. Thus, they *engaged* with the content through *practising* examples on their A4-sized whiteboards with the teacher while she was explaining and doing the procedures with them on her big whiteboard. *Competition* was another motivating factor in learners getting started and completing the game-based worksheets.

The learners were quick to start with the game-based worksheets from the start and were therefore quick to finish, with extra time to mark their work. Learners from the experimental group seemed to work faster than the comparison group, which could be due to learners' motivation to *form goals* and *complete goals*, and the questions being neatly set out on one page (*visual*). Learners from the comparison group sometimes had to page back and forth to see pictures on one page and match them to pictures on another, which was time consuming and confusing for some. Learners took longer to complete the game-based worksheet on division, but were motivated to continue working quickly to win due to the *competitive* element of the worksheet.

Learners in the comparison group followed their usual routine of opening the textbook, finding the activity, and completing it. As mentioned before in Figure 4.10 on observation number 3, learners from the comparison group started off slowly and with the motivation from their teacher, they gained momentum to start working. Some learners were talking to each other instead of getting to work, which affected how they completed the activity. One of the reasons why learners avoid starting with an activity is due to the length of procedures needed to complete the work, or the difficulty of the work. It may also have been due to having to complete the work individually, which they might not have understood completely.

4.5.3 Observations pertaining only to the experimental group

Only the experimental group was observed for observation number 2, 'game influence on learners' attitude towards working with peers'. The idea of a game led learners to wanting to work together (collaborating/*interacting/engaging*), especially when they could compete in teams of two for one of the game-based worksheets. Overall, learners called each other over to sit together in order to complete the game-based worksheets. It was noted that they wanted to work together because they seemed excited to sit next to someone that could offer support, and so they checked with each other frequently to see if their answers matched. Also, learners from different teams helped each other even though they were competing. It seemed important for them that everyone got to finish the game. Thus, they showed an attitude of preference towards working together, which is also summarised in Table 4.4, as six out of eight observations were ‘excellent’ and the other two were ‘average’.

Observation number 5, ‘learners’ *engagement* with peers (collaboration)’, was also observed six out of eight times as being ‘excellent’, and two out of eight times as ‘average’. Learners from the experimental group showed a high level of *engagement/interaction,* which was due to their comfort in talking and asking for help. Learners asked if they could be three in a group so that they could have more support and input from each other.

Table 4.4 shows the same findings for observation numbers 2, 5, and 10, which was observed two out of the possible eight observations as being ‘average’, and the other six out of eight times as being ‘excellent’. Although the comparison group were not observed for these three main observation numbers, extra observation notes were made under comments that were complementary to the observations made of the experimental group. The experimental group seemed to rely on each other for support during the learning process. They also tried to complete the work on their own, but when help was needed, they asked for help and learned from each other. The experimental group’s higher achievement could have been due to the support and explanations shared between learners during which they used their *short-term memory* and *long-term memory* to remember their peer’s explanations and apply it to their own worksheet.

Not only did learners have each other as support, but two of the four game-based worksheets (multiplication and division), requiring *critical thinking* in routine procedures, included number clues on the worksheets which learners could use to determine whether they had gotten the correct answers or not. When learners *discovered/explored* their mistake because it did not fit into the answers provided in the worksheets, they sought help from each other and compared their answers. The fact that these two game-based worksheets included clues to answers may have supported learners in the completion of the worksheets. In contrast with the experimental group, the comparison group was noted to sometimes ask peers for help even though the instructions were that learners complete the textbook activities individually. There were learners who required guidance from their teacher or group leader, which points to a need for support. Thus, collaboration plays an important role in learners' learning, because these learners clearly needed help from a person instead of the explanations from the textbook.

4.6 SEMI-STRUCTURED INTERVIEWS

The mathematics teacher who facilitated the intervention participated in two interviews consisting of the same questions (see Addendum I). The first interview was held prior the start of the intervention, and the second interview was held after the intervention period of four weeks. The interview questions were asked in English, but the teacher preferred to answer in Afrikaans. English translations of the transcripts are included as Addendum J (the Afrikaans transcripts are available on request).

The interviews were transcribed word for word and coded according to the predetermined codes (interfaces from the GOM) in a separate document. The interfaces (game attributes) were discussed in the theoretical framework of this study in Section 2.6. Reading the interview transcriptions a few times made it easier to notice the predetermined codes and review comments made on the document. Since predetermined codes were used in coding the transcripts, bias was limited.

4.6.1 Comparison of the two interviews

The coded transcripts made it easy to see which sentences or parts of sentences were relevant and which were trivial. These sentences or parts of sentences were neatly organised in Table 4.5 into meaningful sentences. Both interviews' answers to the same questions are provided under each question of the interview. The following table also functions as a comparison between the two interviews. Interview 1 refers to the interview held prior to the start of the intervention and interview 2 refers to the interview held after the intervention period. The teacher's quoted words are italicised in the following table.

Table 4.5: Comparison between the mathematics teacher's answers from interview 1 and interview 2

Interview 1	Interview 2
1. What role does collaboration have on a learners' development?	
The teacher stated that collaboration *could change the fun aspect* of developing. Her opinion that *children like to work together* (collaborate) rests on whether one *groups them correctly*. The wrong combination of learners in a group could lead to them showing *none* or *less progress*.	The teacher repeated that through collaboration, learners were having *more fun in the classroom*, although *one does not always know if there is learning taking place*. She further believed that if learners have *more fun, a class will be more pleasant* for the learners.
2. How does a game-based worksheet influence a learner's engagement with the content?	
The teacher mentioned that learners had *more fun* learning through game-based worksheets and were *more enthusiastic.* They *wanted to work*, instead of having to. She further stated *they were more excited* about the content. Learners' goal formation and goal completion were influenced. Due to excitement about the game, they *wanted to do better* and *get it right*. When a *reward is connected* or learners are *competing with each other*, as well as *doing it as a group*,	The teacher believed that the game-based worksheets influenced learners on a motivational level, stating that they are *more driven* by it, and *"want to" get to the answer*, instead of "have to". She mentioned that in simply *saying "just carry on"*, which refers to a normal everyday routine, *they might not be as driven*.

Interview 1	Interview 2
learners have more *fun* and *it motivates them.*	
3. What teaching styles do learners prefer?	
The teacher insisted on learners working individually, but with the assistance of a *group leader* (high achieving learner) who *helps the one who's stuck (struggling learners*). The group setup of her class gave a *different feeling in* that they had support. She stated that when teaching, her learners *need to be focused* and that group work should not be used *when it comes to understanding the work*. Therefore, her reasons for avoiding collaboration were that learners *sometimes become distracted*, *make jokes*, or *do not take the work so seriously*. Although, she mentioned that there is place for collaboration, for example, with *data* handling learners can *gather the information and do it together*, but not with multiplication. The teacher's personal goal for the teaching style that she used was to *get through the work and make sure they understand*. One of her teaching styles included learners having small A4 size whiteboards on which they practised examples with their teacher and engaged in active learning when	According to the teacher, *it is not only the style that is important, but the explanation of the work because* they *want to know what* they *understand.* In the teacher's experience, *it was not always necessarily fun*, especially when one does not understand the content in order to play the game. She stated that *for certain learners it is fun*, referring to *a child with insight, but for a child who struggled, it wasn't fun because he*/she *still did not understand the work*.

Interview 1	Interview 2
she mentioned that they *want to get their boards up* and *wants to get it right*.	
4. What learning styles do learners prefer?	
The teacher believed that all teachers play a role in influencing learners' learning style preference. She stated that *the way teachers explain will have an impact on what* they *choose*. Since she was a teacher who *interacts* with the learners and *walks around*, her learners prefer *engagement*. Furthermore, she believed that learning by having *fun is always choice number one*. Although she knew that one *cannot spend half the time on fun and the other half on the work*, it could still be made *fun as much as possible* by the teacher since mathematics in *sadly not always fun*.	The teacher believed that there *needs to be a combination and a balance, and not only one style,* including *games sometimes*. She also explained that *sometimes, it needs to be the child discovering on their own, and sometimes the teacher needs to give [explanation]*. In her experience, learners *just did a practical the other day and the children loved to read scales*. Furthermore, during the year the teacher got to know her learners, and found that they preferred *to be explained to*. *They want the teacher to do the explaining, because then* they *understand the work better.*
5. Do learners focus and listen more carefully when they need the information to be able to play a game? If they do, what influence do you think does it has on their development in mathematics?	
According to the teacher, the learners *like to know how to play a game, the rules*, and *the instructions* in order for it to be *fair*. Since they *want to be fair*, they would *listen better* because they *want to achieve success*. The teacher believed that *it would mostly be the child who is left behind, or the ADHD*	The teacher stated that learners' *main motivation* to *listen* better was when *they think it will be for* marks. The teacher added that *as soon as they know it's more a game, they might not be as focused, but as soon as they know that it is connected to a reward, whether it is for a dot*

Interview 1	Interview 2
child who is up and down who will focus better. Thus, a game might have an effect on high achieving learners' listening skills and focus because *the stronger child will focus anyway*. Therefore, games will mostly have an influence on the development of struggling learners.	(referring to her reward system in class) *or to show a mark to his/her father on* his/her *report cards, then there is definitely more focus.* Thus, if a game is connected to a reward, learners will focus better.
6. What elements would you include in a lesson to make it interesting and enjoyable for learners?	
The teacher included A4 sized whiteboards for each learner to practise examples on while the teacher was explaining to them, as well as on their own. She *noticed the boards work fantastic* because she could *immediately see what the child understands or not* when they lifted boards up in the air *without losing time*. She also used *rubber shapes* that were thrown around the classroom and *the child who gets* (catches) *it* would give an answer to her question. She used *apparatus* to explain concepts, which *makes things fun* and learners *enjoy it a lot*. She included more elements like *building things*, for example, using *toothpicks* and *Jelly Tots* (soft gum sweets), which meant that *they get something afterwards* and it motivated them to finish. She would sometimes	The teacher expressed a desire for learners to *learn through play and* for them *to discover on their own*, but she stated the reality that *there is only so much time* and teachers are *pressured by the programme from the state* (referring to the CAPS document). Therefore, time constraints and the volume of the CAPS document did not allow for play and discovery all the time as the teacher would have preferred it. Another time constraint she added was having to *give results, deliver results, take responsibility for those results*, and being held accountable by *parents, the state, and oneself*. She further explained that although one adds play and discovery, which adds *more fun, you won't achieve what you want to.*

Interview 1	Interview 2
incorporate *group work [for them] to pressure each other* as *healthy competition*.	
7. What are your beliefs and attitude towards using game-based worksheets in the mathematics classroom?	
The teacher believed that when a game-based worksheet is designed where *one answer gives a clue for the next one*, learners could *immediately realise* and *see where he/she is making a mistake*. The teacher liked that a game-based worksheet could have *something fun that could lead* them *to correct* themselves. She *realised* that it is *important to alternate* between methods used in the classroom, and that *one should actually do something like that* (including game-based worksheet) *once a week.*	The teacher was *very open to it* (referring to game-based worksheets). She stated that *if time allows it,* she *would use it as revision* at *the end of a period of time to see if they understand the work.*
8. How would you describe a quality educational game?	
According to the teacher, if a *game can get you to your end goal, then it is a quality game*. She continued to say that *any activity's goal should be to see if* the learners *mastered that which is expected of them*. Only *a few questions* are necessary to *test the objective and to see if the skill has been achieved*. Therefore, the end results should show development in skills that were meant to be	The teacher first mentioned *challenges*. Secondly, she stressed the importance of incorporating the different cognitive *levels*. She mentioned *knowledge, discovery, challenges and routine* (referring to the four cognitive levels: Knowledge, routine procedures, complex procedures, and problem-solving). She would have preferred that it *count much more marks and [be]*

Interview 1	Interview 2
developed. Another quality criteria mentioned by the teacher is the appearance of the game-based worksheet. *If it looks good, then it is interesting to the children and then they "want to" do it*, and *a picture helps.* She mentioned that *how it* (quality educational game) *is structured is important* in that it will help *motivate them.* If it is *neat* it could motivate learners *to do it neatly*. It also *needs to be well organised, shouldn't confuse them, and they should easily understand the activity so that* they *can reach success.*	*completed over a longer period of time.* The game-based worksheets (used during the intervention) had *been more knowledge,* and the teacher realised that due to *time constraints, one cannot assess all four* cognitive levels. The teacher suggested that there be worksheets for *the child who is only capable of doing the knowledge*-based questions, *but also a more challenging one* for other learners. The teacher showed preference for the game-based worksheet on division since the learners *had to physically do the work* (routine procedures) *to get the "Bingo" row. Matching column A to B* (referring to the game-based worksheet on nets of 3D-objects) was described as *very easy* and *completed over a short period of time.* This could be used *as an introduction to assess pre-knowledge.* According to the teacher, a quality educational game is one that supports the goal of the lesson. If it is to test *pre-knowledge, then it should only include knowledge-based questions. If it is to test the scope of the work, then it needs to include all four aspects* (cognitive levels). The teacher added that *it is*

Interview 1	Interview 2
	still difficult to set something like that up.
9. What positive influences do you think game playing has on a learner's development?	
The teacher added that the *AMESA papers and Conquesta that learners write together half surprised* her *how a weak learner* (low-achieving learner) *had done well together with a strong learner* (high-achieving learner). These two learners are an example of heterogeneous pairs, and in this case, the low-achieving learner did not let the high-achieving learner do all the work, *he did his part.* Therefore, in the teacher's experience, the low-achieving learner "*shines" a little bit more than you would have thought.* Apart from learners being influenced on a *social* level when working in collaboration, *it can also promote academics*. The teacher stated that an activity should be *80% goal driven and about 20% fun, or 70% goal and 30% fun* to have a positive influence on learners' development. If it is just *"fun fun fun fun fun" all the time, even though you reach your goal, he*/she may only remember the fun *and not remember or realise what he*/she *just did*. Game playing could be positive when the	The teacher believed that *if the game is put together right, including challenging questions,* and learners *sit together* (collaboration) *to solve problems, the game can make a big contribution* to learners' development. The teacher gave her opinion that *it could be very good to develop these children's brains to do problem-solving.* She also described the AMESA and Conquesta papers as being *focused on the challenging questions,* requiring *problem-solving* skills, which *is a big gap in children's* development. She further believed that even though it influences learners' *academics*, it also teaches learners to *look outside the box*. *Games could play a very big role in* developing learners to think *outside the box*, and *not necessarily the knowledge that needs to be transferred.* The teacher *didn't think that there was any child who did not like* the game-based worksheets, and that *all the classes would have liked the fun part* by doing the work *in another way.* She also wished that

Interview 1	Interview 2
content is engaging enough that learners *talk about the work and not about the weekend*.	the learners could have *fun for a longer time so that they can see that mathematics can be fun.* When learners did *practical work, they realised that what* they *need to do* (learn) *now, will be applied in society when he*/she *is 30 years old,* and that *they are actually going to use mathematics in the future.*

The following section summarises the answers that were organised in Table 4.5 above. This was done according to the predetermined codes (components and interfaces of educational game design from the GOM), which were selected from the theoretical framework of this study.

4.6.2 Summary of the interviews according to the components and their interfaces of educational games

The answers from the two interviews presented in Table 4.5 are summarised in Table 4.6 below according to the following interfaces from the theoretical framework: play, exploration, challenges, engagement, critical thinking, goal formation, goal completion, competition, practice, fun, interaction, visual, logical, mathematical, computational, short-term memory, and long-term memory. Interfaces that are similar and share the same discussion are: exploration, critical thinking and discovery; engagement and interaction (referring to collaboration); goal formation and goal completion; visual and logical; short-term memory and long-term memory.

The headings provided in the darker shade of grey are the components (for example, game space) of educational game design, and the codes in the left column include the interfaces (game attributes) of each component. Some of the interfaces are grouped together, which means that that which is discussed under one interface is the same for the other interface that it is combined with.

Table 4.6: Summary of the data from interview 1 and interview 2 according to the interfaces selected from the GOM

Codes (Interfaces)	Data from interview 1 and interview 2
1. GAME SPACE	
1.1 Play	First, games get learners excited about the content. Play involves rules and instructions, which learners want to know in order to play fairly and achieve success, therefore they will focus more and listen better. Since learners also need to understand the content before they are able to play the game, low-achieving learners will mostly benefit from the game through being motivated to listen and focus. Play is limited by the time constraints and the volume of the CAPS document that needs to be assessed at the end of each year. The mathematics teacher makes use of methods such as learners using A4-sized whiteboards to make it seem like play, without losing instructional time. Other methods that can be applied involve the throwing of rubber shapes, using apparatus, and building shapes to imitate a play environment while learning is taking place. If there is an imbalance and more time is spent on play and discovery, the lesson objectives will not be reached. A balance between fun and work, could include incorporating a game once a week.
1.2 Exploration	Exploration, critical thinking and discovery is used for problem-solving. Game-based worksheets motivate and drive learners to get to the correct answers. Exploration and discovery makes a lesson interesting and enjoyable for learners, for example, physically holding a rubber 3D-object and counting its faces or building 3D-objects with toothpicks and Jelly Tots allow learners to explore and discover the answers on their own. Game-based

Codes (Interfaces)	Data from interview 1 and interview 2
	worksheets could include clues or a set of correct answers, which gives learners the opportunity to discover when they are making a mistake. This allows learners to further explore and critically think about their procedures in order to correct their mistakes and try again.
1.3 Challenges	Quality educational games include challenges and questions on all four cognitive levels (knowledge, routine procedures, complex procedures, and problem-solving). Complex procedures and problem-solving questions should be included in educational games to provide learners with challenges. There should also be differentiation between worksheets where low-achieving learners start by completing more knowledge-based questions, while high-achieving learners complete more challenging questions.
1.4 Engagement	Children enjoy collaborating, although correct grouping (heterogeneous grouping) is important to avoid less or no progress. High-achieving learners can support low-achieving learners. Therefore, collaboration gives the feeling of being supported. It is important for learners to approach challenging questions in collaboration to maximise the potential of a low-achieving learner when paired with a high-achieving learner. Academics improve through collaboration by developing learners' problem-solving skills. A preferred teaching style includes learners engaging in active learning with their teacher through the use of A4-sized whiteboards; Thus, one of the preferred learning styles also included collaboration due to the teacher using engaging practices when teaching. Content should be made engaging enough, for example, through

Codes (Interfaces)	Data from interview 1 and interview 2
	a game-based worksheet, to motivate learners to discuss the content instead of other trivial topics. Collaboration is an appropriate method that can be used in data handling.
2. VISUALISATION SPACE	
2.1 Critical thinking	As mentioned above (see 1.2 Exploration).
2.2 Discovery	As mentioned above (see 1.2 Exploration). Through practical work, learners made the discovery that mathematics is linked to their everyday lives and that they will use their knowledge of mathematics in the future.
2.3 Goal formation	The use of individual A4-sized whiteboards gets learners excited about lifting their whiteboard for the teacher to see and to do it correctly. Game-based worksheets bring out learners' enthusiasm. Learners "want to" instead of "have to" complete the work, and they want to do better and do it correctly. Learners set goals according to rewards, for example, if they are completing a game-based worksheet for marks that will show on their report cards, they will focus and listen well. Rewards could also include, for example, learners being allowed to eat their Jelly Tots after builing their 3D-objects with toothpicks and Jelly Tots.
2.4 Goal completion	
2.5 Competition	Learners compete in groups as the class tables are arranged into groups, on the amount of rewards (dots) they have at the end of the term, and the group with the most dots, receive a further bigger reward. Collaborative competition makes learning fun and motivates learners to engage with the content.
2.6 Practice	Practising examples on learners' individual whiteboards while the teacher explains on the class's whiteboard is

Codes (Interfaces)	Data from interview 1 and interview 2
	used to get through the work without losing time, while also making sure that the learners understand. Practising using this method makes learning more interesting and enjoyable for the learners.
3. ELEMENT SPACE	
3.1 Fun	Fun is learners first choice of learning style and makes class more pleasant. As mentioned, each learner uses an A4-sized whiteboard, which makes the learning experience fun. Game-based worksheets and collaboration add fun to a class. Discovering and correcting mistakes are made fun through game-based worksheets. These include clues or a set of correct answers that allow learners to correct mistakes and develop feelings of success with every correct answer before completing the next. Although, learners with insight and understanding will have more fun playing a game than struggling learners. Mathematics is not always considered fun, but the teacher can try to make it as fun as possible while keeping a balance between fun and work, as well as using a variety of learning styles. There is limited time that could be spent on play, therefore there is limited time that could be spent on fun. An educational game should be 80 or 70% goal, and the other 20 or 30% fun. When fun is part of the everyday routine, learners might only remember the fun, and not necessarily what they were meant to learn.
4. ACTOR SPACE	
4.1 Interaction	As mentioned above in the current table (See 1.4 Engagement).

<table>
<tr><th>Codes (Interfaces)</th><th>Data from interview 1 and interview 2</th></tr>
<tr><td colspan="2">5. PROBLEM SPACE</td></tr>
<tr><td>5.1 Visual</td><td rowspan="2">In designing a quality educational game, only a few questions are necessary to determine whether learners understand. A neat appearance motivates learners to “want to” complete it, and do so neatly. The structure of an educational game is important, for example, it should be well organised and instructions should be easy to understand in order to avoid confusion and maximise the time during which learners practise their skills and complete the activity.</td></tr>
<tr><td>5.2 Logical</td></tr>
<tr><td>5.3 Mathematical</td><td>A quality educational game will develop the skill that it was designed to develop. The objectives of a game-based worksheet should guide the teacher as to which cognitive levels to include in it, for example, if the objective is to test the scope of a topic, questions on all four cognitive levels should be included. It should be completed over enough time in order to include the four cognitive levels mentioned above (See 1.3 Challenges in this table). An educational game can make a significant contribution to learners’ development when they sit together and work on challenging questions. Learners prefer explanations that will provide them with a deep understanding of the content being dealt with.</td></tr>
<tr><td>5.4 Computational</td><td>Learners need to be focused and understand the work, therefore no collaboration should be applied in the topic of multiplication.</td></tr>
</table>

<table>
<tr><th>Codes (Interfaces)</th><th>Data from interview 1 and interview 2</th></tr>
<tr><td>5.5 Short-term memory</td><td rowspan="2">Learners will focus and listen to what the rules and instructions of a game are that they need to remember in order to achieve success when playing a game after the content has been dealt with. High-achieving learners usually focus and listen well without the motivation of a game. In contrast, struggling learners are influenced through game-based worksheets to focus and listen well because they need to follow the rules and instructions to get to the answers. Game-based worksheets could serve as an introduction to a lesson (testing pre-knowledge), including knowledge-based questions, as well as revision on a completed topic, including the scope of that topic. Finally, solving problems and working on challenging questions together develops learners to think outside the box and apply such methods in real-life situations that will arise in the future.</td></tr>
<tr><td>5.6 Long-term memory</td></tr>
</table>

4.7 SUMMARY

The results from the intervention were analysed and interpreted according to highest or lowest average percentages. The results for the experimental group show positive influences on learners' achievement, which resulted from learners' development in mathematics. The observations also provide positive findings on learners' behaviour and attitude towards mathematics by implementing collaborative game-based worksheets through collaboration. The interviews were summarised according to the interfaces of educational game design, which provides a deeper understanding of the importance of designing educational games as opposed to any game, and what interfaces are most important in educational games. The following chapter will answer the research questions and provide conclusions and recommendations.

CHAPTER 5 DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter provides the answers to the research questions. The research results and findings, together with the literature review, are discussed under each research question. This chapter also includes a summary of the findings, conclusions, implications and recommendations, as well as the limitations of this study.

5.2 DISCUSSION OF THE RESEARCH QUESTIONS

The aim of this study was to explore the developmental influences of the implementation of collaborative mathematics games in Grade 6. The two secondary questions answer the main research question and are based on the components and interfaces of the educational game design of Amory et al.'s (2011) GOM.

5.2.1 Secondary question 1: How are educational games beneficial to learning and development in mathematics?

The experimental group scored higher than the comparison group in two pre-tests (nets of 3D-objects and division), as well as in three post-tests (multiplication, nets of 3D-objects, and division). The two lowest average percentages out of the four topics were scored in multiplication and division, and these were the two topics that increased the most from the pre-test to the post-test. The game-based worksheets in multiplication and division included logical number clues, which allowed learners to discover when they made a mistake and to explore their mistakes in order to correct themselves. These clues positively influenced learners' chance of achieving success. Clues made the game-based worksheets more fun and motivated learners, which was observed in their eagerness and willingness to start, and to correct themselves.

The average pre-test to post-test increase was 13.85% for the experimental group, and 9.57% for the comparison group, which is a difference of 4.28%. If there had been the same average increase from pre-test to post-test for both groups, the experimental group would have ended up with an average of 85.67% since the initial difference was 1.39%. Instead, they scored 89.95%, which is 4.28% more than what might have been expected. Therefore, an increase in development was seen in the experimental group.

Both groups scored higher average percentages for all four topics' post-tests than their pre-tests. However, the experimental group had more fun and were influenced greatly on multiplication and division involving procedural knowledge. In addition, observations on the experimental group's level of fun in the topics from 'space and shape' included pictures, an easy to complete game-based worksheet. It also consisted mainly of knowledge-based questions, which contributed to the experimental group's achievement. The comparison group's two highest average percentages between the four mathematics topics in the pre-tests as well as in the post-tests were scored in nets of 3D-objects and symmetry. These two topics, which are covered in the content area 'space and shape' and contain mainly facts and knowledge-based questions, were the lowest of the four cognitive levels. Nets of 3D-objects and symmetry are visual, colourful, practical, and include physical shapes/apparatus, which are characteristics of a game. Therefore, the game-like features of these two topics may have been one of the reasons that the comparison group scored their highest averages in these topics. This further contributes to the idea that games have a positive influence on learners' development.

In terms of the observations, the highest scale observed in the experimental group was 'excellent' at 91%, and in the comparison group 'average' at 64%. It showed that learners normally function at an 'average' to 'excellent' level while following a routine and working from their textbooks. Learners use their short-term memory and long-term memory when they focus on the content being taught in order to remember it. In this vein, a part of why the experimental group's level was observed as being 'excellent' at 91% were the game-based worksheets that motivated them to "want to work" and keep their focus on the teacher's instruction. The fun and 'different' effect that games bring to the classroom would eventually become ordinary and part of the routine, and the game-based worksheet would later start to lose its effect. The mathematics teacher explained that teaching the content specified in the CAPS document in the allocated time frame is a difficult task. According to the teacher, the CAPS document allows no more than one game per week if one is even possible.

Nevertheless, it was observed that the experimental group completed the game-based worksheets very quickly. This was partly due to their understanding of the content because they focused better since they knew they needed to be able to do the work in order to participate in a game. The teacher believed that low-achieving learners would benefit mostly from the game-based worksheets' motivation to focus more because the high-achieving learners would give their attention either way. She also mentioned that when a reward is connected to a task, learners listened and focused better.

Enjoyment, fun, excitement, motivation, and enthusiasm were observed during the implementation and completion of the game-based worksheets by the experimental group. These observations were not present during the observations of the comparison group, who completed the textbook activities, which is part of the reason for their lack of motivation to get started. Firstly, game-based worksheets that include number clues, hidden secrets, crossword puzzles (using numbers instead of words), and a classic Bingo format contributed to learners having more fun because it created a playful environment. In addition to the physical game-based worksheets, according to the teacher, learners' fun came from their understanding of the work because they were required to understand the work in order to be able to play. One of the learners said that while she was busy completing the game-based worksheet, when she understood the work, it made mathematics fun for her. Apart from requiring understanding, learners also want to know the rules and instructions in order to play fairly and deserve their achievement.

5.2.2 Secondary question 2: How does collaboration influence learning and development in mathematics?

As mentioned in the previous section, the experimental group's highest increase from pre-test to post-test was in multiplication (19.51%) and division (24.11%). The comparison group's highest increase from pre-test to post-test was in symmetry (14.5%) and division (13.24%). Since both groups increased in average percentages from the pre-tests to the post-tests for every mathematics topic respectively, it indicates that achievement is possible with or without game-based worksheets. Although both groups increased in division, the experimental group increased almost double the percentage that the comparison group increased. This may not only be due to the game-based worksheets consisting of number clues, but also due the incorporation of collaboration. Since the comparison group completed the textbook activities, and scored higher average percentages in every topic's post-test than the pre-test, it is concluded that development took place in both groups.

The experimental group's two lowest pre-test average percentages were in multiplication and division, which are also the two topics that showed the highest increase from the pre-test to the post-test. Both topics are covered under the content area 'numbers, operations, and relationships', and contain mainly routine procedures, which is the second level of the four cognitive levels. Since the experimental group improved the most in multiplication and division, which require routine procedures that use skills from a higher cognitive level than the topics from 'space and shape', it is concluded that in addition to number clues on the game-based worksheets, collaboration had a positive influence on learners due to explaining and comparing their answers as another means of checking for mistakes and correcting themselves. In addition, the increase in multiplication and division are considered extremes since these two post-tests have the highest average percentage amongst all the post-tests from both the experimental and comparison groups. Thus, the experimental group achieved these extreme increases due to the addition of collaboration. As mentioned in the previous section, an increase from pre-tests to post-tests was due to the game-like features that these two topics comprise. Also, an additional increase would be due to the incorporation of collaboration. Therefore, it is concluded that since the comparison group's highest post-test average percentage were for nets of 3D-objects and symmetry, and they completed the textbook activities individually, collaboration had little or no influence on these two topics.

According to the literature, heterogeneous groups should function as support and allow learners to be accountable for their individual work (Dockett & Perry, 2010). The experimental group was grouped into heterogeneous pairs by the teacher, and collaboration took place in the form partnerships as support structures, which led to learners achieving success together. Collaboration would not have been enjoyed if one learner ended up giving all the answers, which leads to limited collaboration and minimal understanding (Noddings, 1989). The experimental group was indicated as 'excellent' in seven out of eight observations when it came to their enjoyment of collaboration.

According to the mathematics teacher, collaboration is an appropriate method for content areas such as data handling, which includes practical work. However, both multiplication and division fall under the content area 'numbers, operations and relationships'. She also stated that collaboration is appropriate for problem-solving questions and that learners sitting together and figuring the answers out (discovery) would develop their critical thinking skills in terms of solving problems and thinking outside of the box. The literature confirms that discovery, comprehension and problem-solving skills develop during collaboration (Du Plessis et al., 2007).

The experimental group showed positive attitudes toward working together and enjoyed collaborating, especially when learners were competing against each other in pairs. The learners wanted to compete and felt more confident to compete in pairs. Competition caused the learners to start and finish more quickly as well as more accurately since their highest increase from pre-test to post-test was in division, which used the Bingo format that was completed in the competition. The teacher used competition between the groups according to the classroom's seating arrangements, of which only one group per class that reached the most rewards during a term were rewarded with something special at the end of each term. Learners from the comparison group were talking to each other and not rushed to get started even though the teacher gave the instruction that they could begin with the activity.

An important observation was noted in the comparison group. Their instructions were that they complete their textbook activity individually. Struggling learners were allowed to ask their group leaders for help or they could ask their teacher when they faced a challenging question. Thus, support was provided, which indicated that collaboration cannot entirely be excluded from a class. Learners referred to the group leader or teacher for help and not the textbook explanations. Some learners enjoyed working individually when performing routine procedures in multiplication and division, during which they wanted to concentrate on their own.

5.2.3 Summary

The primary research question is: How do collaborative games influence learners' development in the Grade 6 mathematics classroom? It has emerged that the collaborative game-based worksheets had a positive influence on learners' development in mathematics according to the developmental areas listed under specific aims in the CAPS document. Confidence and competence developed by including number clues in some of the game-based worksheets, which provided learners with a better chance at succeeding in every question. This was because they could see their own mistakes if the answer did not fit in with the number clue given on the worksheet. Also, social competence develops when learners collaborate and learn how to compete (Pareto et al., 2012). Social competence is needed in order for learners to take in the instructional support from another person (Bodrova, 1997). Love of mathematics developed through having fun and enjoying something different from the usual routine, while their curiosity was piqued by searching for their own mistakes and correcting these themselves. Development in creativity is mostly influenced by the content area 'space and shape', for example, where learners investigate and experiment with shapes (Amory et al., 2011). The problem-solving cognitive level requires creativity in finding solutions by thinking outside of the box. Recognition of mathematics as part of human nature was described by the teacher during the interviews as learners having commented on something that they had just learned and realising that it would be used in society and that they would use the skills that they developed in mathematics in the future. This is connected to learners developing a critical awareness of mathematics relationships (social, environmental, cultural, and economic relations).

5.3 CONCLUSIONS

Four main conclusions were drawn from this research.

1. **It was clear that the interfaces provided by the theoretical framework not only worked well, but proved to be essential in making the games educational and conducive to learners' mathematical development.**

The results and findings indicate that the components and interfaces that were used to design educational game-based worksheets positively influenced learners in their mathematical development. These include: play, exploration, challenges, engagement, critical thinking, discovery, goal formation, goal completion, competition, practice, fun, interaction, visual, logical, mathematical, computational, short-term memory, and long-term memory (Amory et al., 2011). Together with the literature review, the theoretical framework for future digital learning resources and learning material in mathematics education could be designed using the above-mentioned as quality criteria.

Game-based worksheets should be designed with educational purpose (Cojocariu & Boghian, 2014), and used to supplement the content that the teacher is trying to convey to learners, for example, being used as an introduction to a lesson or revision on the scope of a mathematics topic (Ramani & Eason, 2015). Furthermore, the content in the game-based worksheets should be designed according to, and correlate with the specifications of the CAPS document, or the specific curriculum used by the school where the game-based worksheet will be implemented.

Physical appearance should be neat, which includes a good structure, organised content, and/or pictures. Clear instructions and explaining the rules helps to avoid confusion (Cojocariu & Boghian, 2014). The relevant cognitive levels of the game-based worksheets should be taken into consideration in terms of the aims and objectives that the game is designed to achieve, for example, for an introduction or revision. The appearance and complexity of a game could make an activity seem more difficult or less difficult. When an activity is too difficult, learners lose interest and disengage from it (Chen & Law, 2016). Also, effective games offer support in the form of collaboration that helps learners to make sense of and attain knowledge (Ter Vrugte et al., 2015). Therefore, in designing quality educational games, and considering the GOM, collaboration is also necessary. The game-based worksheets designed for and used in the intervention each contained a combination of the identified interfaces from the GOM. Thus, the positive influence of these interfaces on learners' development in mathematics led to learners' higher achievement in mathematics.

2. **Game-based worksheets that include clues play an important role in learners' development in confidence and competence, and provide learners with a higher chance at achieving success.**

Differentiated educational games help address learners' diverse needs (Trinter et al., 2015), for example, low-achieving learners need support, which could be in the form of clues in an activity, whereas high-achieving learners do not. Designing the game-based worksheets with number clues supported learners by providing them with a higher chance at achieving success than they would have had without it. This is supported by Chen and Law's (2016) idea that learners should feel competent when attempting to complete a task. The number clues also allowed learners to discover whether an answer was either correct or incorrect, depending on if it fitted or did not fit into the number clues provided. The synthesis, analysis, evaluation, and critical thinking used during game-based learning (Chen & Law, 2016) are applied by learners when correcting their mistakes. Since number clues serve as support in guiding learners towards the correct answers, and have positive influences on learners' achievement through their development in confidence and competence, it is concluded that game-based worksheets that include number clues can be used successfully even without collaboration, allowing learners to work more independently.

3. **Collaboration in heterogeneous pairs contributes to the increase of learners' achievement in mathematics.**

Both groups had higher post-test average percentages for every topic covered during the intervention period. It is concluded that no matter the format of the activity, learners can develop and achieve success. Although, the experimental group nearly increased by double the percentage in division than the comparison group. Therefore, the high increase experienced by the experimental group was due to the addition of collaboration. Game-based learning has the potential to connect learners by involving an entire class and creating an active learning environment (Cojocariu & Boghian, 2014). Thus, collaboration in heterogeneous pairs, and the combination with the game-based worksheets positively influenced learners' development, which led to the experimental group's higher increase in achievement from the pre-test to the post-test.

During the interviews, the mathematics teacher believed that low-achieving learners would benefit the most from collaboration because the learner has someone that supports him/her. She also mentioned that when doing problem-solving, it was the low-achieving learner's time to shine because he/she would not have been able to complete it on their own, but with the added support, low-achieving learners would put in some effort. The literature adds that low-achieving learners benefit the most from heterogeneous groupings (Chen et al., 2012), and that heterogeneous groups work when learners complete their work individually but less able learners have a source of support in the form of a more knowledgeable peer (Dockett & Perry, 2010).

4. **The implementation of collaborative game-based worksheets is influenced by time constraints.**

Open-mindedness towards incorporating different teaching and learning styles into the mathematics classroom, and possessing the intention to improve on teaching practice is constrained by the demands and volume of the CAPS document. The teacher was of the opinion that the demands and volume of the CAPS document allow limited deviation from the curriculum to incorporate fun into the classroom through collaborative games. The curriculum leaves little room for the practise and development of problem solving (highest cognitive level), and would require more time for development in this area. Teaching specific concepts and skills is required by the curriculum to be achieved in a specific time frame (Ramani & Eason, 2015), which could be one of the reasons why learners who dislike mathematics in Grade 4 have almost doubled when measured again in Grade 8, according to the TIMSS results (Mullis et al. 2016). Time that learners used to spend playing with peers created the opportunity for learners to practise their skills (Trinter et al., 2015). This become less the higher the grade due to the level of complexity also increasing, and this may thus become more time consuming. It is concluded that in order to make optimal use of the time allocated to specific topics in the CAPS document, games could be incorporated as introductions to lessons or as revision in order to acquire the benefits of incorporating games.

5.4 IMPLICATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This study describes the influences that collaborative mathematical games have on learners' development in mathematics. The findings of this study add to the existing literature on educational games and collaboration, with the addition of developmental areas stated in the CAPS document that are influenced through the incorporation of collaborative game-based worksheets. These findings made it possible to detect learner development from the implementation of the collaborative game-based worksheets. This could raise awareness of the benefits and positive influences of collaborative games on learners' development. It could possibly promote the use of games and motivate not only mathematics teachers, but allow teachers also to incorporate educational games into their own classrooms to make it more fun and enjoyable. The framework and information on educational game design could be helpful to mathematics teachers since the game design is based on mathematics.

The collaborative game-based worksheets used during the intervention of this study were designed using the activities from the Grade 6 mathematics textbook. Thus, by using the textbook, which consists of activities that are in accordance with the specifications of the CAPS document, teachers already possess the educational content with specific aims and skills. Teachers simply need to change the format into a game or game-based worksheet such as the ones designed for this study.

Further research is required on the development of educational games and the appropriate implementation of collaboration. Recommendations for future research are as follows, studies could be conducted on:

- Pre-test-post-test design implementing weekly game-based worksheets on each of the five content areas in mathematics over a period of time.
- Determining what cognitive levels pertain mainly to which content areas in mathematics, and the appropriate approach to achieving success in each cognitive level, for example, individually or collaboratively.
- Learners' mathematics developmental areas stated in the specific aims of the CAPS document and practices on how to measure development in these areas.
- The direct relationship between learner development in mathematics in terms of the specific aims of the CAPS document and learner achievement in mathematics.
- Pre-test-post-test design using three groups, completing a number of activities on the same mathematical content over a specific period of time. One group should complete the activities in collaboration in heterogeneous pairs, while the second group collaborates in homogeneous pairs, and the third group works individually.
- Determining the reasons why, according to TIMSS, the percentage of learners in Grade 4 who dislike mathematics more or less doubles when they are measured again in Grade 8, as well as an action plan.

5.5 LIMITATIONS OF THIS STUDY

The limitations of this study include a lack of randomisation, therefore a lack of generalisability. This limitation exists due to the use of a quasi-experimental design because participants in existing groups (classes) were used in this study, therefore the sample is not a true representation of the population, and generalisations cannot be made from the results and findings. Some degree of randomisation is applied when learners are randomly divided into new classes each year by a computer system. Also, the classes were assigned alphabet letters to their grade number in the order: 'S', 'K', 'U', and 'L', which were used to assign classes to either the experimental or comparison group. Some degree of equivalence between the experimental and comparison group was noticed when both groups' pre-test average percentages were compared (see Figure 4.1). Both groups scored highest in their pre-tests on nets of 3D-objects and symmetry, and the lowest in multiplication and division.

The Grade 6 mathematics teacher was the only participant used for the interviews, therefore the results could have been different if there were more mathematics teachers, including differences in gender, race, or school. During the interviews, the teacher may have been influenced by external or internal factors while answering the interview questions. Since the same questions were asked in both interviews, these concerns were avoided to some extent since the second interview could be used to confirm what was said in the first interview, or to determine what had changed since the first interview.

During the observations, subjectivity was a concern. This was corrected by member checking with the teacher, who also observed the learners while teaching them. Each class was observed four times, which means that both the experimental and the comparison group were observed eight times, which provides enough data to determine and use the averages of each. Also, four different mathematics topics were covered under two out of the five content areas.

In the design of the game-based worksheets, four topics were chosen from two content areas for the intervention, which included observation. Although each content area consists of many different topics, ‘numbers, operations, and relationships’ mainly requires skills in routine procedures (second cognitive level), while ‘space and shape’ mainly requires knowledge that is on the lowest cognitive level. Thus, conclusions can be generalised to some extent to topics under these two content areas.

5.6 FINAL REFLECTIONS

In the process of completing my Honours degree in Education in Learning support in 2015, I decided to use the knowledge that I have gained over my five years of studying to make a contribution to mathematics. I have had a love and passion for this subject for as long as I can remember, and I desire for children to have the same feelings towards mathematics, as well as in general regarding their daily tasks. I felt that children are stuck in routines, covered in homework, follow fixed extra-curricular schedules, and are controlled by the demands of parents. Children, in general, are growing up too fast and too much is expected from them too soon. This opinion was substantiated when I started teaching at the beginning of 2015, while I was working on my Honours degree.

I started doing research on how to make mathematics fun and enjoyable, and learned that it was possible. The literature review was difficult to complete in getting the information organised, although the literature found was interesting and shocking. The international assessors of TIMSS conducted a study on whether learners liked or disliked mathematics. From 1995 to 2015, the percentage of Grade 4 learners who said they disliked mathematics nearly doubled to the highest percentage of 34% in Grade 8 students. It is unclear why learners dislike the subject the older they get, and I would like to contribute to getting learners to like mathematics and keep liking it.

With this research, I hope to have provided new perspectives on the incorporation of collaborative games in the classroom, and to inspire mathematics teachers to be open minded about collaboration and to learning how to design one’s own games. A final desire is that teachers will see and know their importance in the life of a child.

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ADDENDUMS

ADDENDUM A: LETTERS OF PERMISSION AND CONSENT

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

Dear Principal,

I am currently enrolled as a Masters of Education student at the University of Pretoria. I would like to ask you whether I may conduct a part of my research at your school in the second school term in 2017.

The topic of my research is: The influence of games, through collaboration, on learners' development in mathematics in Grade 6. The aim of my research is to explore the results of the implementation of games in the mathematics classroom, through collaboration, on a learner's development in mathematics. The focus of the research is on the practical application of learning content in the form of games that will promote development in mathematics.

The objectives of the study are to promote the use of games in the mathematics classroom and to raise awareness in teachers of its influence on learner development in mathematics. It is also an objective to increase learner achievement through the positive learner development.

This study involves an intervention, observation and two interviews. The mathematics teacher will be asked to voluntarily participate in a semi-structured interview before and after the intervention, to be held in her own classroom at a time convenient to her.

The data collection procedure includes: intervention, semi-structured interviews and observations. The intervention will involve the four Grade 6 mathematics classes. Two classes as the experimental group (receiving the intervention) and the other two the comparison group (not receiving the intervention). All learners will stay in their classes and receive the same lesson, designed and taught by their Grade 6 mathematics teacher. Learners will be divided into diverse pairs by their teacher for the intervention. The intervention is an educational game-based worksheet, designed by me, according to the specifications of the CAPS document, using the questions from the Grade 6 mathematics textbook. There are four Grade 6 classes, two of which will receive the intervention, completing the activity from their textbook in accordance with the specifications of the CAPS (Curriculum and Assessment Policy Statement) document, but in the form of a game-based worksheet. The other two classes will complete the activity from their textbook. The questions are the same for both the experimental group (receiving the intervention) and comparison group (not receiving the intervention). Therefore all four classes of grade 6 learners will be doing the same work with their teacher, except two classes will be using game-based activities and two classes will be using the text book activities to do the work. There will be no disruption of their normal class activities. I will observe the learners during the four lessons, and complete an observation schedule.

The 4 game-based worksheets will be used to determine an average, used as a post-test, against the average of a pre-test. Learners will start each week completing an activity (pre-test), testing their pre-knowledge on the specific topic which will be tested and observed on the Friday of that week. The pre-test is designed using the Grade 5 mathematics textbook ("Oxford Suksesvolle Wiskunde"), testing learners' pre-knowledge on each topic. Since the experiment takes place in the second school term, the Grade 5 mathematics textbook is used to provide activities on learners' pre-knowledge where activities are not available in the content from the first term of the Grade 6 textbook on these topics.

I will hand out letters of informed consent to the Grade 6 mathematics teacher, learners, and parents/guardians of the learners. In the letters, I will explain that participation is voluntary, with the choice of discontinuing at any point during the study. It will also be explained that participants' identities will be kept confidential and will not be mentioned in the dissertation or any other publication. The interviews will be recorded and kept in safe storage, and will not be used in any presentation where their voices could be identified.

After completion of the study, the material will be stored at the University of Pretoria in the Science, Mathematics and Technology Department. All data collected will only be used for academic purposes and will be locked up for safety and confidentiality purposes. All data collected with public funding may be made available in an open repository for public and scientific use.

If you agree to allow me to conduct the research, please complete the consent form below.

If you have any further questions, please contact me or my supervisor at the numbers or email addresses given below.

Angelique van Coller
Contact number (C): 076 225 6550
E-mail: angeliquevc@gmail.com

Dr. Sonja van Putten (Supervisor)
Contact number (W): 012 420 5657
E-mail: sonja.vanputten@up.ac.za

………...

I, ______________________________________ (name and surname), principal of ________________________________ (school), hereby **grant / do not grant** permission for Ms van Coller to conduct the research described above in my school.

Signed: ______________________________ Date: ________________________

……………………………………………..………………………………………..

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

Dear Grade 6 Mathematics Teacher,

I am currently enrolled as a Masters of Education student at the University of Pretoria. I would like to ask you whether I may conduct a part of my research in your classroom in Term 2 in 2017. The topic of my research is: The influence of games, through collaboration, on a learner's development in mathematics in Grade 6. The aim of my research is to explore the results of the implementation of games in the mathematics classroom, through collaboration, on learners' development in mathematics. The focus of the research is on the practical application of learning content in the form of games that will promote development in mathematics. The objectives of the study are to promote the use of games in the mathematics classroom and to raise awareness in teachers of its positive influences on learner development in mathematics. It is also an objective to increase learner achievement through positive learner development.

This study involves an intervention and two interviews with you, one before and one after the intervention. You will be asked to voluntarily participate in a semi-structured interview before and after the intervention, to be held your classroom at a time convenient for you. For the intervention, I would like to design a game-based worksheet for you to use during the lesson you have planned, during which I will observe the learners on the research topic.

The data collection procedure includes: intervention, semi-structured interviews and observations. The intervention will involve the four Grade 6 mathematics classes. Two classes as the experimental group (receiving the intervention) and the other two the comparison group (not receiving the intervention). All learners will stay in their classes and receive the same lesson, designed and taught by you, their Grade 6 mathematics teacher. You will divide learners into diverse pairs for the intervention. The intervention is an educational game-based worksheet, designed by me, according to the specifications of the CAPS document, using the questions from the Grade 6 mathematics textbook. There are four Grade 6 classes, two of which will receive the intervention, completing the activity from their textbook in accordance with the specifications of the CAPS (Curriculum and Assessment Policy Statement) document, but in the form of a game-based worksheet. The other two classes will complete the activity from their textbook. The questions are the same for both the experimental group (receiving the intervention) and comparison group (not receiving the intervention). Therefore all four classes of grade 6 learners will be doing the same work with their teacher, except two classes will be using game-based activities and two classes will be using the text book activities to do the work. There will be no disruption of their normal class activities. I will observe the learners during the four lessons, and complete an observation schedule.

The 4 game-based worksheets will be used to determine an average, used as a post-test, against the average of a pre-test. Learners will start each week completing an activity (pre-test), testing their pre-knowledge on the specific topic which will be tested and observed on the Friday of that week. The pre-test is designed using the Grade 5 mathematics textbook ("Oxford Suksesvolle Wiskunde"), testing learners' pre-knowledge on each topic. Since the experiment takes place in the second school term, the Grade 5 mathematics textbook is used to provide activities on learners' pre-knowledge where activities are not available in the content from the first term of the Grade 6 textbook on these topics.

I will hand out letters of informed consent to you, the learners, and parents/guardians of the learners. In the letters, I will explain that participation is voluntary, with the choice of discontinuing at any point during the study. It will also be explained that participants' identities will be kept confidential and will not be mentioned in the dissertation or any other publication. The interviews will be recorded and kept in safe storage, and will not be used in any presentation where their voices could be identified.

After completion of the study, the material will be stored at the University of Pretoria in the Science, Mathematics and Technology Department. All data collected will only be used for academic purposes and will be locked up for safety and confidentiality purposes. All data collected with public funding may be made available in an open repository for public and scientific use.

If you agree to allow me to conduct the research, please complete the consent form below.

If you have any further questions, please contact me or my supervisor at the numbers or Email addresses given below.

Angelique van Coller
Contact number (C): 076 225 6550
E-mail: angeliquevc@gmail.com

Dr. Sonja van Putten (Supervisor)
Contact number (W): 012 420 5657
E-mail: sonja.vanputten@up.ac.za

……………………………………………………………………………………………….....

I, ____ (name and surname), the Grade 6 mathematics teacher at __________________________________ (school), hereby **grant / do not grant** permission for my participation in the research described above.

Signed: _______________________________ Date: ___________________________

……………………………………………………………………………………………….....

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

Dear Parent/Guardian,

I am currently enrolled as a Masters of Education student at the University of Pretoria. The topic of my research is: The influence of games, through collaboration, on learners' development in mathematics in Grade 6. The aim of my research is to explore the results of the implementation of games in the mathematics classroom, through collaboration, on a learner's development in mathematics. The objectives of the study are to promote the use of games in the mathematics classroom and to raise awareness in teachers of its influence on learner development in mathematics. It is also an objective to increase learner achievement through the positive learner development.

I would like to implement an intervention. The intervention will not disrupt the learners normal class activities as all learners will complete the same work, but in different formats. The Grade 6 mathematics teacher will design and teach her lessons as she usually would. The intervention will take place in Term 2, on four Fridays, during the learners' mathematics lesson. There are four Grade 6 classes, two of which will receive the intervention, completing the activity from their textbook in accordance with the specifications of the CAPS (Curriculum and Assessment Policy Statement) document, but in the form of a game-based worksheet. The other two classes will complete the activity from their textbook. The questions are the same for both the experimental group (receiving the intervention) and comparison group (not receiving the intervention). Therefore all four classes of grade 6 learners will be doing the same work with their teacher, except two classes will be using game-based activities and two classes will be using the text book activities to do the work. The game-based worksheet, designed by me, will include an element of a game for example, a competition, fun or puzzles. The teacher will arrange learners into pairs. I will observe the learners in the classroom during each of the four lessons.

The four game-based worksheets will be used to determine an average, used as a post-test, against the average of a pre-test. Learners will start each week completing an activity (pre-test), testing their pre-knowledge on the specific topic which will be tested and observed on the Friday of that week. The pre-test is designed using the Grade 5 mathematics textbook ("Oxford Suksesvolle Wiskunde"), testing learners' pre-knowledge on each topic. Since the experiment takes place in the second school term, the Grade 5 mathematics textbook is used to provide activities on learners' pre-knowledge where activities are not available in the content from the first term of the Grade 6 textbook on these topics.

All learners will remain anonymous and their details and those of the school will not be disclosed at all. If you do not wish for your child to take part, it is not going to disadvantage them, because they will be completing the same questions from their textbook and may decide to work in pairs or individually.

After completion of the study, the material will be stored at the University of Pretoria in the Science, Mathematics and Technology Department. All data collected will only be used for academic purposes and will be locked up for safety and confidentiality purposes. All data collected with public funding may be made available in an open repository for public and scientific use.

If you grant/do not grant permission for your child to be part/not be part of the research, please complete the consent form below. If you have any further questions, please contact me or my supervisor at the numbers or email addresses given below.

Angelique van Coller
Contact number (C): 076 225 6550
E-mail: angeliquevc@gmail.com

Dr. Sonja van Putten (Supervisor)
Contact number (W): 012 420 5657
E-mail: sonja.vanputten@up.ac.za

…………………………………………………………………………………………………..…

I, ____ (name and surname), parent/guardian of __________________________________ (learner's name and surname), hereby **grant / do not grant** permission for her/him to participate in the research described above.

Signed:________________________________ Date: _________________________

…………………………………………………………………………………………………..

ADDENDUM B: LETTER OF ASSENT TO LEARNERS

Faculty of Education

Fakulteit Opvoedkunde

Lefapha la Thuto

Beste leerders,

Ek is `n Meesters student in Onderwys aan die Universiteit van Pretoria. Ek moet `n studie doen en oor die resultate skryf. Die studie se naam is: Die invloed van speletjies, deur samewerking, op `n leerder se ontwikkeling in Wiskunde in Graad 6.

Ek wil graag `n intervensie doen om uit te vind wat die invloed van speletjies op jou ontwikkeling in wiskunde is. Ek fokus daarop om speletjies te gebruik in die klas waar jy saam met `n klasmaat werk. Dit beteken julle kan mekaar help deur saam te werk.

Jou Graad 6 juffrou sal die les vir jou aanbied soos gewoonlik. Elke klas sal dieselfde lesaanbieding ontvang. Twee uit die vier Graad 6 klasse sal gebruik word om die werkkaart, in die vorm van `n speletjie, te voltooi en die ander twee klasse sal uit die handboek werk. Die werkkaart word opgestel deur die vrae presies so vanuit die handboek te gebruik, daarom sal geen leerder benadeel word as hy/sy nie wil deel wees hiervan nie. Die twee klasse wat nie gekies word om die werkkaart te voltooi nie, word dus nie benadeel nie, aangesien julle dieselfde werk doen, net in `n ander formaat. Elke klas se werk sal aan die einde van die periode gemerk word en slegs die leerders wie hiervan wil deel wees, se punte sal gebruik word vir die navorsing.

Daar is vier werkkaarte, een vir elke Vrydag in Kwartaal 2, vir vier Vrydae. Aan die begin van die week sal al die Graad 6'e hersiening doen uit die Graad 5 wiskunde handboek, om vas te stel wat julle kan onthou. Julle sal op die Vrydag die Graad 6 werk behandel oor dieselfde werk wat julle van Graad 5 hersien het deur die week.

Jy het die keuse of jy wil deel wees van die intervensie of nie. Geen name of ander persoonlike inligting sal gebruik word in die navorsing nie. Voltooi asseblief die afskeurstrokie om aan te dui of jy sal deel neem aan die navorsing. Indien jy nie wil deelneem nie, sal jy nie benadeel word nie, en sal jou punte nie gebruik word nie.

As jy enige vrae het, is jy welkom om my te kontak deur een van die onderstaande nommers of epos adresse te gebruik.

Angelique van Coller
Kontak besonderhede: 076 225 6550
E-pos: angeliquevc@gmail.com

Dr. Sonja van Putten (Toesighouer)
Kontak besonderhede: 012 420 5657
E-pos: sonja.vanputten@up.ac.za

....

Ek, ____ (naam en van), `n leerder van _______________________________________ (skool) **gee toestemming / gee nie toestemming** om deel te neem aan die navorsing wat hierbo beskryf is.

Geteken:___________________________________Datum: ____________________

....

ADDENDUM C: PRE-TESTS

Topic 1: Multiplication

Activity 5, page 224, numbers 1.a, 1.d, 1.g, 1.j, 1.k, 1.m (Oxford Suksesvolle Wiskunde Leerdersboek Graad 5):

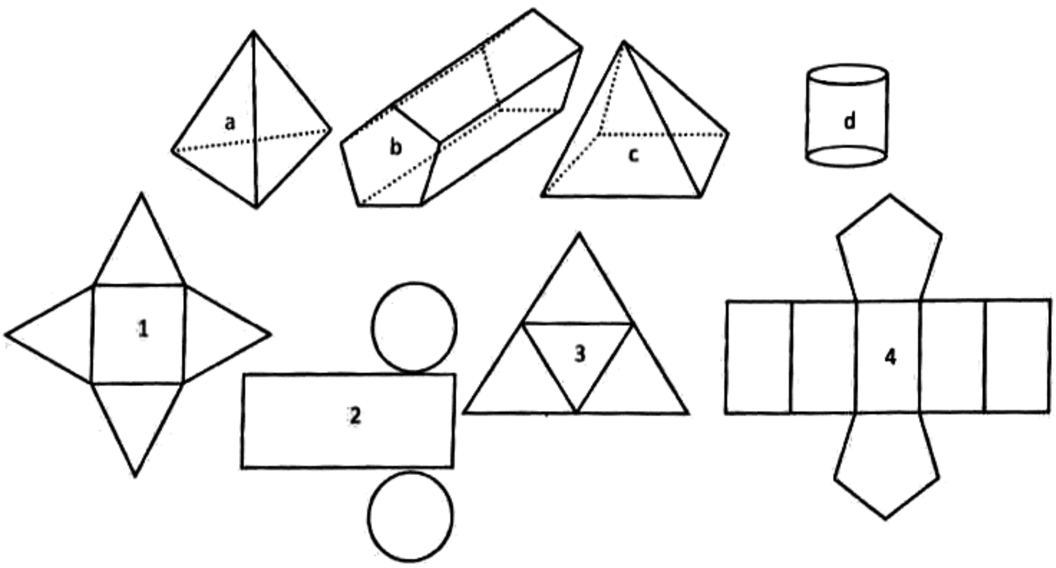
1 Bereken deur faktore te gebruik om getalle af te breek.

a 175 × 24	b 268 × 25	c 327 × 28
d 436 × 32	e 565 × 36	f 608 × 42
g 743 × 45	h 897 × 48	i 956 × 54
j 257 × 56	k 524 × 63	l 875 × 72
m 324 × 75	n 676 × 84	o 949 × 96

Topic 2: Nets of 3d objects

Activity 4, page 135-136, number 4 (Oxford Suksesvolle Wiskunde Leerdersboek Graad 5):

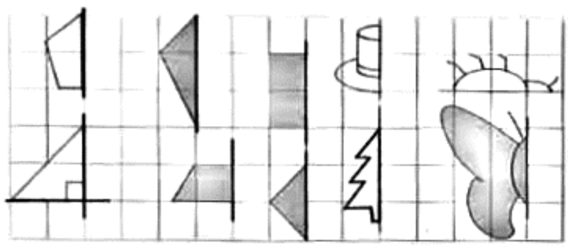
4 Pas elkeen van die tekeninge van 'n 3D-voorwerp hieronder met die tekening(e) van die vorm(s) wat gebruik kan word om die voorwerp te bou.



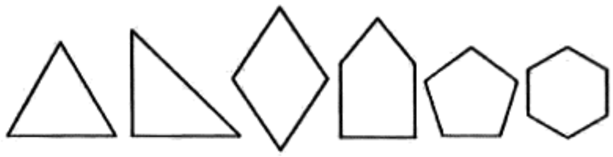
Topic 3: Symmetry

Activity 1, page 144, numbers 1, 2 and 3 (Oxford Suksesvolle Wiskunde Leerdersboek Graad 5):

1 Trek elke vorm na op vierkante ruitpapier. Voltooi die tekening.



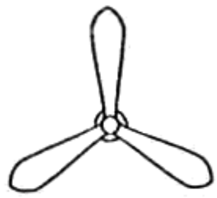
2 Hoeveel simmetrielyne kan jy in elke vorm hieronder kry?



3 Sê hoeveel simmetrielyne jy kan vind in:

a elke letter hieronder

b die propeller



Topic 4: Division

Activity 3, page 149, numbers 1.a, 1.g, 2.b and 2.e (Oxford Suksesvolle Wiskunde Leerdersboek Graad 5):

1 Skat eers elke antwoord. Bereken dit dan en kontroleer dit.

a $121 \div 11$	b $228 \div 12$	c $325 \div 13$
d $476 \div 14$	e $555 \div 15$	f $672 \div 16$
g $765 \div 17$	h $828 \div 18$	i $969 \div 19$

2 Skat eers elke antwoord. Bereken dit dan en kontroleer dit.

a $336 \div 21$	b $507 \div 39$	c $946 \div 43$
d $952 \div 56$	e $806 \div 62$	f $936 \div 78$
g $924 \div 84$	h $864 \div 96$	i $765 \div 85$

ADDENDUM D: POST-TESTS FOR COMPARISON GROUP (TEXTBOOK ACTIVITIES)

Topic 1: Multiplication

Activity 5, page 100, numbers 1, 2 and 3 (Oxford Suksesvolle Wiskunde Leerdersboek Graad 6):

Bereken:

1	1 794 × 4	2	2 029 × 5	3	3 755 × 6
4	7 375 × 7	5	8 487 × 8	6	9 075 × 9

Activity 6, page 101, numbers 2, 7 and 16 (Oxford Suksesvolle Wiskunde Leerdersboek Graad 6):

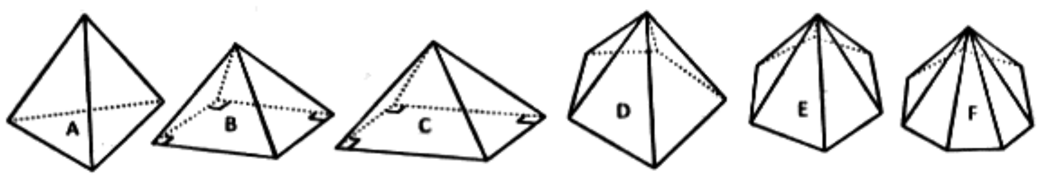
Bereken:

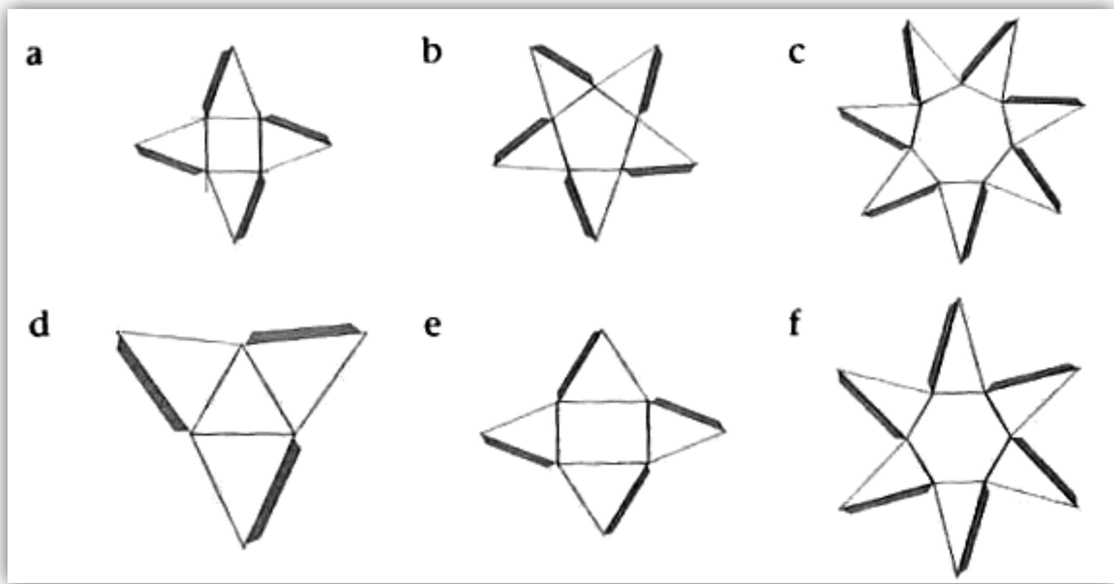
1	1 802 × 11	2	2 594 × 12	3	3 008 × 13
4	4 188 × 14	5	5 999 × 15	6	6 457 × 16
7	7 844 × 17	8	8 752 × 18	9	9 286 × 19
10	1 429 × 21	11	7 306 × 37	12	8 114 × 49
13	8 875 × 57	14	4 389 × 64	15	6 849 × 76
16	3 555 × 83	17	5 199 × 95	18	9 999 × 99

Topic 2: Nets of 3d objects

Activity 2, page 107-108, number 3, first two sentences (Oxford Suksesvolle Wiskunde Leerdersboek Graad 6):

3 Pas die nette by die regte 3D-voorwerpe. Skryf die letter neer van die vorm langs die letter van die net. Die nette is op kolletjiespapier geteken sodat jy dit kan natrek en die 3D-voorwerp bou.





Topic 3: Symmetry

Activity 1, page 117, numbers 2 and 3 (Oxford Suksesvolle Wiskunde Leerdersboek Graad 6):

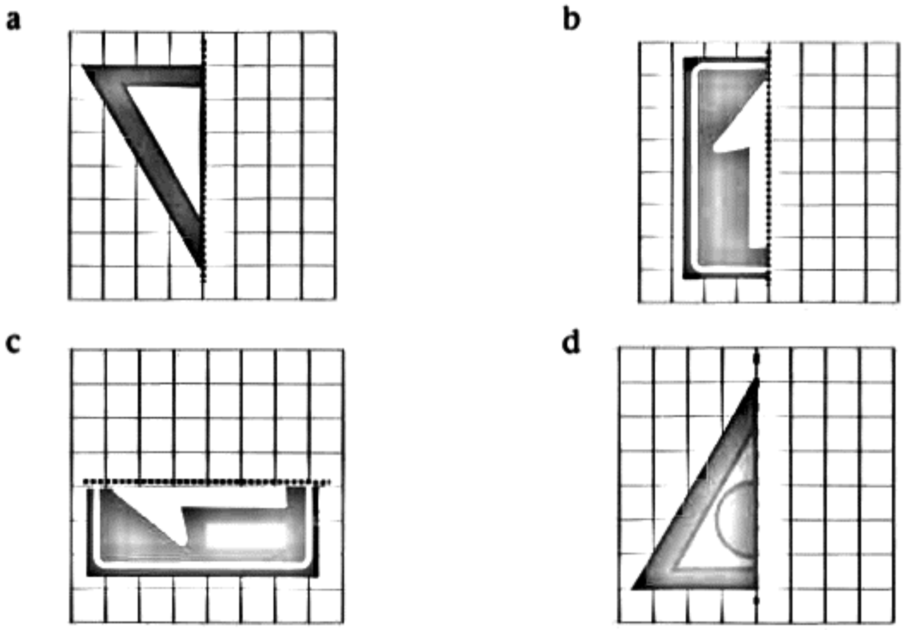

2 Hoeveel simmetrielyne kan jy in elke letter hieronder vind?

TINY MAXS

3 Bestudeer elkeen van die volgende tekeninge en skryf neer hoeveel simmetrielyne daar in elke tekening is.

Activity 2, page 119, number 3a and 3.c, second sentence (Oxford Suksesvolle Wiskunde Leerdersboek Graad 6):

3 **Maak afskrifte van die tekeninge hieronder op blokkiespapier. Voltooi die tekening deur refleksie in die simmetrielyn te gebruik.**



Topic 4: Division

Activity 4, page 124, numbers 8, 10, 12 and 14 (Oxford Suksesvolle Wiskunde Leerdersboek Graad 6):

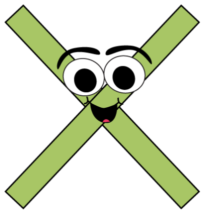
7	714 ÷ 17	8	810 ÷ 18	9	988 ÷ 19
10	546 ÷ 21	11	874 ÷ 38	12	774 ÷ 43
13	969 ÷ 57	14	744 ÷ 62	15	924 ÷ 77
16	924 ÷ 84	17	864 ÷ 96	18	891 ÷ 99
19	888 ÷ 37	20	667 ÷ 23	21	899 ÷ 31

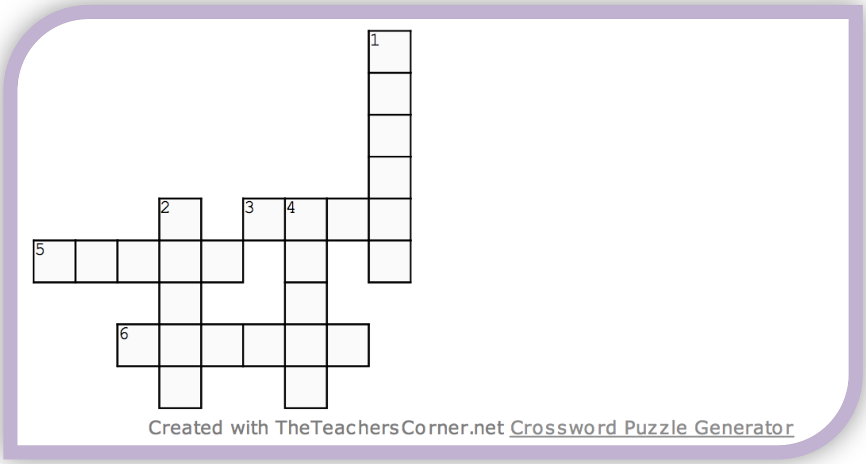
ADDENDUM E: POST-TESTS FOR EXPERIMENTAL GROUP (GAME-BASED WORKSHEETS)

VERMENIGVULDIGING

Naam en Van: ________________________________ Datum: 2017 - 04 - 21

Werk in pare en voltooi die antwoorde op die blokkiesraaisel





DWARS:

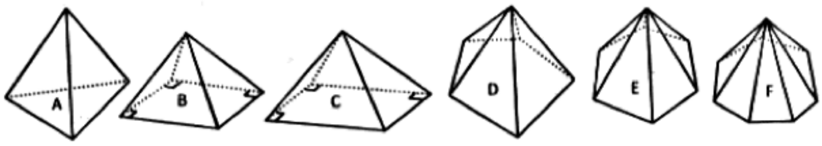
3. 1794 × 4
5. 2594 × 12
6. 7844 × 17

AF:

1. 3555 × 83
2. 3755 × 6
4. 2029 × 5

NETTE VAN 3D-VOORWERPE

Naam en Van: ____ Datum: 2017 - 05 - 05

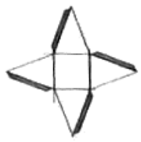
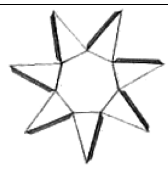
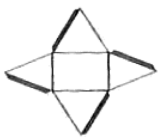


G E H E I M E K O D E

Werk in pare.

Pas die nette by die regte 3D-voorwerpe.

Skryf die letter neer van die vorm langs die letter van die net.

a		
b		
c		
d		
e		
f		

SIMMETRIE

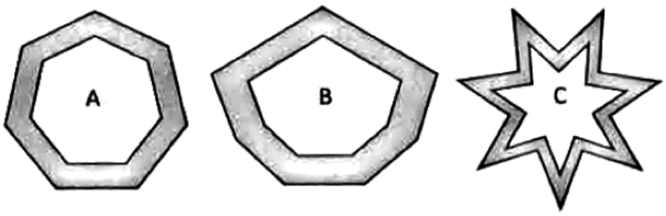
Naam en Van: ____ Datum: 2017 - 05 - 12

Werk in pare en voltooi die vrae ☺

Hoeveel simmetrielyne kan jy in elke letter hieronder vind?

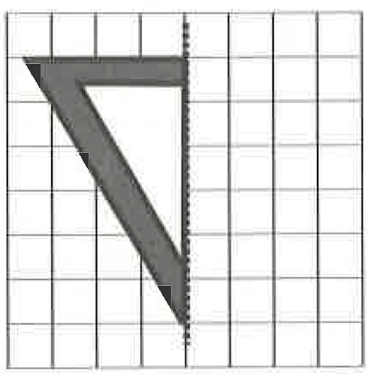
TINY MAXS

Bestudeer elkeen van die volgende tekeninge en skryf neer hoeveel simmetrielyne daar in elke tekening is.

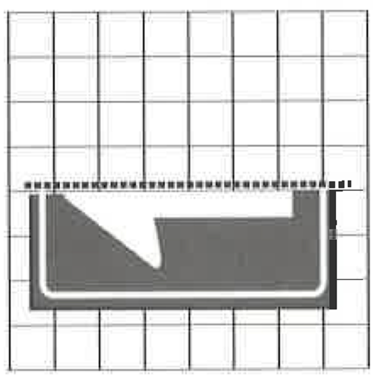


Voltooi die tekening deur refleksie in die simmetrielyn te gebruik.

a



c



Deling

Naam en Van: ___________________________________ Datum: 2017 - 05 - 19

Speeleltjiereëls:

Werk in pare en speel teen mekaar.

Elke leerder kry `n ander kaart met al die antwoorde op, maar in verskillende volgordes.

Daar is ook verkeerde antwoorde tussen in.

Na elke antwoord bereken is, kleur dit in voordat jy na die volgende som aanbeweeg.

Om te wen, moet jy die 4 antwoorde in `n ry kry (vertikaal, horisontaal of diagonaal).

Die eerste een met 4 korrekte antwoorde in `n ry, wen!

Bereken die volgende somme:

1. **810 ÷ 18**
2. **546 ÷ 21**
3. **774 ÷ 43**
4. **744 ÷ 62**

Plak jou kaart hier:

“Bingo” cards:

11	9	27	21
26	12	45	18
42	19	14	37
33	15	41	23

12	23	37	14
26	42	33	41
18	11	27	15
45	9	21	19

12	37	15	19
9	45	11	21
33	14	26	41
27	23	42	18

14	45	21	27
23	12	33	42
37	26	41	15
11	18	9	19

27	37	15	26
9	19	18	11
33	45	41	14
12	21	42	23

41	15	27	23
42	33	19	21
37	11	14	9
26	18	12	45

Answers to get in a straight line (vertical, horizontal or diagonal): 45; 26; 18; 12

11	9	27	21
26	12	45	18
42	19	14	37
33	15	41	23

12	23	37	14
26	42	33	41
18	11	27	15
45	9	21	19

12	37	15	19
9	45	11	21
33	14	26	41
27	23	42	18

14	45	21	27
23	12	33	42
37	26	41	15
11	18	9	19

27	37	15	26
9	19	18	11
33	45	41	14
12	21	42	23

41	15	27	23
42	33	19	21
37	11	14	9
26	18	12	45

ADDENDUM F: INTERVENTION RESULTS (PRE-TEST-POST-TEST DESIGN)

INTERVENTION RESULTS DOCUMENTED DURING PRETEST AND POSTTEST												
TOPIC		MULTIPLICATION		NETS OF 3D-OBJECTS		SYMMETRY		DIVISION		TOTAL PRETEST AVERAGE	TOTAL POSTTEST AVERAGE	DIFFERENCE BETWEEN PRE AND POST
DATE		19 APRIL	21 APRIL	2 MAY	5 MAY	8 MAY	12 MAY	15 MAY	19 MAY			
PRE/POST		PRE	POST	PRE	POST	PRE	POST	PRE	POST			
TOTAL		6	6	4	6	21	14	4	4			
EXPERIMENTAL GROUP'S SCORES (6S AND 6U	1	2	4	a	6	15	11	3	4			
	2	4	0	4	6	a	a	1	4			
	3	5	a	4	6	14	10	1	4			
	4	1	6	4	6	18	10	1	2			
	5	2	6	4	6	9	12	4	4			
	6	4	3	4	6	a	13	1	4			
	7	0	6	4	6	16	11	2	4			
	8	2	6	4	6	20	14	4	4			
	9	3	4	a	6	19	12	3	4			
	10	5	a	4	6	18	12	4	4			
	11	5	4	4	6	a	11	4	4			
	12	0	6	4	6	14	13	3	4			
	13	2	5	4	6	9	10	2	4			
	14	5	5	4	6	18	11	4	4			
	15	3	6	4	6	16	10	2	4			
	16	4	4	4	6	20	13	4	4			
	17	5	5	4	6	19	13	3	4			
	18	5	6	4	6	16	11	4	4			
	19	4	4	4	6	15	13	3	4			
	20	5	5	4	6	18	14	3	4			
	21	3	5	4	6	9	11	2	4			
	22	5	5	4	6	14	12	3	2			
	23	4	a	4	a	13	13	3	4			
	24	a	4	4	6	10	10	3	4			
	25	6	6	4	6	17	14	4	4			
	26	4	6	4	6	11	11	4	4			
	27	4	4	2	4	20	a	2	4			
	28	6	5	4	6	18	13	4	4			
	AVERAGE	**3,63**	**4,80**	**3,92**	**5,93**	**15,44**	**11,85**	**2,89**	**3,86**			
	PERCENTAGE	**60,49**	**80,00**	**98,08**	**98,77**	**73,52**	**84,62**	**72,32**	**96,43**	**76,10**	**89,95**	**13,85**
COMPARISON GROUP'S SCORES (6L AND 6K	29	4	5	4	6	18	13	3	3			
	30	2	2	4	4	19	12	2	2			
	31	0	3	4	6	10	12	4	3			
	32	6	5	4	6	21	13	4	4			
	33	6	4	4	6	13	11	4	4			
	34	5	5	4	6	19	12	4	4			
	35	3	5	a	6	17	a	4	3			
	36	2	5	4	6	14	13	4	4			
	37	1	3	2	a	19	13	3	3			
	38	4	4	a	a	16	14	1	4			
	39	6	1	4	6	a	11	1	a			
	40	5	3	2	6	17	12	4	2			
	41	3	4	4	6	18	13	3	3			
	42	6	3	4	6	16	14	0	2			
	43	3	3	4	6	18	13	3	3			
	44	6	6	4	6	16	12	2	2			
	45	2	6	4	6	19	13	4	3			
	46	2	4	4	6	11	12	1	3			
	47	4	6	4	6	6	12	4	4			
	48	2	4	4	6	11	13	1	3			
	49	6	5	2	6	17	11	3	4			
	50	6	5	4	6	13	11	1	3			
	51	6	6	4	a	16	14	1	4			
	AVERAGE	**3,91**	**4,22**	**3,71**	**5,90**	**15,64**	**12,45**	**2,65**	**3,18**			
	PERCENTAGE	**65,22**	**70,29**	**92,86**	**98,33**	**74,46**	**88,96**	**66,30**	**79,55**	**74,71**	**84,28**	**9,57**
DIFFERENCE BETWEEN EXPERIMENTAL AND COMPARISON GROUP		**-4,72**	**9,71**	**5,22**	**0,43**	**-0,94**	**-4,35**	**6,02**	**16,88**	**1,39**	**5,67**	**4,28**
ABSOLUTE DIFFERENCE		**4,72**	**9,71**	**5,22**	**0,43**	**0,94**	**4,35**	**6,02**	**16,88**	**1,39**	**5,67**	**4,28**

ADDENDUM G: OBSERVATION SCHEDULES

Experimental group:

Topic: Multiplication

Date: 2017-04-21 Time: 08:30 Class: 6S

Participants: Experimental group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Active learning; Engaging with teacher
2	Game influence on learners' attitude towards working with peers		×		
3	Learners' motivation to start with the *game-based worksheet*			×	Learners yell "yes" when they hear that they will complete the worksheet
4	Learners' level of fun while completing the *game-based worksheet*			×	
5	Learners' engagement with peers (collaboration)		×		Comfortable to talk and ask for help
6	Learners' enjoyment of the *game-based worksheet*			×	
7	Learners' enjoyment of *collaborating*		×		
8	Learners' development of a love for mathematics			×	Excited
9	Learners' completion of the *game-based worksheet*			×	
10	Learners' learning from peers			×	Work quietly but still helping each other. They use each other as support, and do not constantly rely on one another

Topic: Multiplication

Date: 2017-04-21 Time: 13:05 Class: 6U

Participants: Experimental group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Active learning; Engagement with teacher
2	Game influence on learners' attitude towards working with peers		×		Learners seem to want to work together
3	Learners' motivation to start with the *game-based worksheet*			×	Learners yell "yes" when told they will complete a game-based worksheet
4	Learners' level of fun while completing the *game-based worksheet*			×	
5	Learners' engagement with peers (collaboration)			×	High level of collaboration and comfort
6	Learners' enjoyment of the *game-based worksheet*			×	Excited to start
7	Learners' enjoyment of *collaborating*			×	This class seems to enjoy it more than the previous intervention class
8	Learners' development of a love for mathematics			×	
9	Learners' completion of the *game-based worksheet*			×	Eager to finish before the time to complete the worksheet is up
10	Learners' learning from peers			×	Constantly helping/supporting each other and working well together

Topic: Nets of 3D-objects

Date: 2017-05-05 Time: 8:35 Class: 6S

Participants: Experimental group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Active learning; Eager to answer the teacher's questions
2	Game influence on learners' attitude towards working with peers			×	Learners organise themselves with the same peer they had in the previous worksheet
3	Learners' motivation to start with the *game-based worksheet*			×	
4	Learners' level of fun while completing the *game-based worksheet*			×	
5	Learners' engagement with peers (collaboration)		×		Comfortable to engage, but understood the content well enough to complete most of it on their own
6	Learners' enjoyment of the *game-based worksheet*			×	Learners seem to enjoy getting a worksheet
7	Learners' enjoyment of *collaborating*			×	
8	Learners' development of a love for mathematics			×	Learners seem to enjoy the topic on its own
9	Learners' completion of the *game-based worksheet*			×	Quick finish to the worksheet
10	Learners' learning from peers		×		Learners do not seem to need support as this is an easier topic

Topic: Nets of 3D-objects

Date: 2017-05-05 Time: 12:35 Class: 6U

Participants: Experimental group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Active learning; Learners are attentive and answer questions
2	Game influence on learners' attitude towards working with peers			×	Learners seem excited to sit next to someone for extra support and are ready to help each other
3	Learners' motivation to start with the *game-based worksheet*			×	Learners seem excited to get to the answers and check themselves
4	Learners' level of fun while completing the *game-based worksheet*			×	
5	Learners' engagement with peers (collaboration)			×	High level of engagement
6	Learners' enjoyment of the *game-based worksheet*			×	Learners enjoy the answers being "hidden" as a code and checking behind the board whether they were correct
7	Learners' enjoyment of *collaborating*			×	Great collaboration between peers
8	Learners' development of a love for mathematics			×	Fun and excitement from the game-based worksheet; Seems like learners "want to" work instead of "have to"
9	Learners' completion of the *game-based worksheet*			×	
10	Learners' learning from peers			×	

Topic: Symmetry

Date: 2017-05-12 Time: 8:35 Class: 6S

Participants: Experimental group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Interaction with teacher; Active learning
2	Game influence on learners' attitude towards working with peers			×	Learners seem to enjoy being a part of a team and having support even when it is not used
3	Learners' motivation to start with the *game-based worksheet*			×	Immediately started cutting the worksheet outand working with peers
4	Learners' level of fun while completing the *game-based worksheet*			×	Content seems to be fun on its own
5	Learners' engagement with peers (collaboration)			×	Learners asking whether they may be three learners working together
6	Learners' enjoyment of the *game-based worksheet*			×	
7	Learners' enjoyment of *collaborating*			×	
8	Learners' development of a love for mathematics			×	Symmetry seems to be some of the easier mathematical content which is visually stimulating and fun
9	Learners' completion of the *game-based worksheet*			×	Quick completion
10	Learners' learning from peers		×		Learners do not need a lot of support for this content

Topic: Symmetry

Date: 2017-05-12 Time: 13:05 Class: 6U

Participants: Experimental group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Active learning; Give attention; Interactive questioning and answering
2	Game influence on learners' attitude towards working with peers			×	Learners call each other over to come and sit with them and work together like the previous time
3	Learners' motivation to start with the *game-based worksheet*			×	Eager to start by calling their peer over to get started
4	Learners' level of fun while completing the *game-based worksheet*			×	
5	Learners' engagement with peers (collaboration)			×	High level of collaboration; The best observation of collaboration during the intervention thus far
6	Learners' enjoyment of the *game-based worksheet*			×	Learners seem to enjoy completing everything on one page
7	Learners' enjoyment of *collaborating*			×	It seems natural at this point for learners to work together
8	Learners' development of a love for mathematics			×	The content seems more enjoyable than complex procedures; It seems easy to enjoy
9	Learners' completion of the *game-based worksheet*			×	Quick completion due to all the questions being on one page and neatly set out
10	Learners' learning from peers			×	Explaining to each other; High level of collaboration

Topic: Division

Date: 2017-05-19 Time: 8:35 Class: 6S

Participants: Experimental group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Active learning; Practicing examples on their whiteboards
2	Game influence on learners' attitude towards working with peers			×	Learners compare their answers in the end with that of their peer's as competition
3	Learners' motivation to start with the *game-based worksheet*			×	Learners seem excited to play the game and compete
4	Learners' level of fun while completing the *game-based worksheet*			×	Learners seem very excited to start and listen to how the game is played and completed
5	Learners' engagement with peers (collaboration)			×	Learners engage even though it is still a competition
6	Learners' enjoyment of the *game-based worksheet*			×	There are fun elements to the game
7	Learners' enjoyment of *collaborating*			×	Competition seems to be a motivator for learners to collaborate
8	Learners' development of a love for mathematics			×	Learners enjoy division as a "bingo" game
9	Learners' completion of the *game-based worksheet*			×	Division takes longer to complete as there are procedures to follow
10	Learners' learning from peers			×	Seems to get support through "healthy" pressure in the form of competition; The game aided as support due to it having the correct answers between incorrect answers in a straight line. Therefor learners know whether they made a mistake or not

Topic: Division

Date: 2017-05-19 Time: 12:30 Class: 6U

Participants: Experimental group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Active learning; Use whiteboards to practice examples
2	Game influence on learners' attitude towards working with peers			×	Even though it is a completion, I noticed learners still helping each other
3	Learners' motivation to start with the *game-based worksheet*			×	Learners say "1, 2, 3, start!" together
4	Learners' level of fun while completing the *game-based worksheet*			×	Learners seem to want to compete
5	Learners' engagement with peers (collaboration)			×	Good competition
6	Learners' enjoyment of the *game-based worksheet*			×	Learners made groups of two against two which means two on a team, therefore supporting each other
7	Learners' enjoyment of *collaborating*			×	
8	Learners' development of a love for mathematics			×	
9	Learners' completion of the *game-based worksheet*			×	Learners work well together and follow the instructions; They work quickly to win
10	Learners' learning from peers			×	Learners who made teams of two against other two helped each other by coming up with this way of completing the game in order to be able to learn from each other

Comparison group:

Topic: Multiplication

Date: 2017-04-21 Time: 10:30 Class: 6L

Participants: Comparison group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Active learning; Engagement with teacher
2	Game influence on learners' attitude towards working with peers				N/A
3	Learners' motivation to start with the *textbook activity*		×		It is routine for learners to work from their textbook; It seems expected that learners would start
4	Learners' level of fun while completing the *textbook activity*	×			No element of fun in the textbook activity, only a list of sums
5	Learners' engagement with peers (collaboration)				N/A
6	Learners' enjoyment of the *textbook activity*		×		
7	Learners' enjoyment of *working individually*		×		Some learners seem to enjoy working individually on procedural work such as multiplication
8	Learners' development of a love for mathematics			×	The teacher is excellent at stirring up a love for mathematics in her learners, thus the activity does not seem to
9	Learners' completion of the *textbook activity*			×	Routine behaviour
10	Learners' learning from peers				N/A

Topic: Multiplication

Date: 2017-04-21 Time: 11:10 Class: 6K

Participants: Comparison group

		OBSERVATIONS			
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Active learning; Engagement with teacher
2	Game influence on learners' attitude towards working with peers				N/A
3	Learners' motivation to start with the *textbook activity*		×		It is routine for learners to work from their textbook; It seems expected that learners would start
4	Learners' level of fun while completing the *textbook activity*	×			It is expected; No extra motivation
5	Learners' engagement with peers (collaboration)				N/A
6	Learners' enjoyment of the *textbook activity*		×		
7	Learners' enjoyment of *working individually*		×		Learners engage with the teacher when they struggle individually
8	Learners' development of a love for mathematics			×	Even though the textbook activity does not seem to promote a love for mathematics, the teacher finds a way to do that
9	Learners' completion of the *textbook activity*			×	Learners complete their work as it is expected of them
10	Learners' learning from peers				N/A

Topic: Nets of 3D-objects

Date: 2017-05-05 Time: 10:35 Class: 6L

Participants: Comparison group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Active learning; Questioning and engaging
2	Game influence on learners' attitude towards working with peers				N/A
3	Learners' motivation to start with the *textbook activity*		×		Some learners take a while to get started and need support/motivation; Learners are used to the routine of working from the textbook
4	Learners' level of fun while completing the *textbook activity*		×		Routine is familiar, therefore learners know what to expect from the textbook
5	Learners' engagement with peers (collaboration)				N/A
6	Learners' enjoyment of the *textbook activity*		×		The activities in the textbook are mostly similar, therefore learners know what to expect with nothing new or exciting
7	Learners' enjoyment of *working individually*			×	Learners are used to working individually
8	Learners' development of a love for mathematics			×	Nets of 3D-objects is a fun topic on its own due to it also being visual
9	Learners' completion of the *textbook activity*			×	
10	Learners' learning from peers				N/A Learners are supposed to complete the textbook activity individually, but some learners ask the teacher for help, while others ignore the rules and ask peers for help. This shows they do need some form of support

Topic: Nets of 3D-objects

Date: 2017-05-05 Time: 11:10 Class: 6K

Participants: Comparison group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught		×		Active learning; Learners do not show motivation to listen; Engaging with class
2	Game influence on learners' attitude towards working with peers				N/A
3	Learners' motivation to start with the *textbook activity*		×		Routine to start immediately; Learners are used to starting the activity after the teacher's explanation
4	Learners' level of fun while completing the *textbook activity*		×		Learners appear neutral;
5	Learners' engagement with peers (collaboration)				N/A
6	Learners' enjoyment of the *textbook activity*		×		The activity does not appear to be exciting
7	Learners' enjoyment of *working individually*		×		Some learners enjoy working individually, while others need some help
8	Learners' development of a love for mathematics		×		Even though 3D-objects are fun as it is, it is still routine in the way they complete the activity
9	Learners' completion of the *textbook activity*			×	
10	Learners' learning from peers				N/A Learners complete the textbook activity individually; Learners sit in groups in which the teacher has appointed a group leader as one of her classroom strategies to offer help to learners and when they fall behind with their own work, they can ask the teacher

Topic: Symmetry

Date: 2017-05-12 Time: 10:30 Class: 6L

Participants: Comparison group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Great teacher; Active learning using examples; Challenging questions and learners answering; Very interactive
2	Game influence on learners' attitude towards working with peers				N/A
3	Learners' motivation to start with the *textbook activity*		×		
4	Learners' level of fun while completing the *textbook activity*		×		Routine
5	Learners' engagement with peers (collaboration)				N/A
6	Learners' enjoyment of the *textbook activity*		×		The content seems to be enjoyable on its own and visually stimulating
7	Learners' enjoyment of *working individually*		×		This class works quietly and hard
8	Learners' development of a love for mathematics			×	Content is enjoyable; It could promote a love for mathematics naturally
9	Learners' completion of the *textbook activity*			×	
10	Learners' learning from peers				N/A Even though instructions were to work individually from the textbook, there are learners who quietly ask their peers for help

Topic: Symmetry

Date: 2017-05-12 Time: 11:10 Class: 6K

Participants: Comparison group

OBSERVATIONS

NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught		×		Excellent teacher; Very interactive with the learners; I noticed that some learners who usually do not listen, still do not listen even though the teacher is going beyond with her explanation
2	Game influence on learners' attitude towards working with peers				N/A
3	Learners' motivation to start with the *textbook activity*		×		Teacher influence learners to start working by clapping her hands and saying "let's begin"; It took learners a while to gain momentum to get started
4	Learners' level of fun while completing the *textbook activity*		×		
5	Learners' engagement with peers (collaboration)				N/A
6	Learners' enjoyment of the *textbook activity*		×		It seems like enjoyable content to the learners
7	Learners' enjoyment of *working individually*		×		
8	Learners' development of a love for mathematics			×	It seems that learners like symmetry and the visual component of it
9	Learners' completion of the *textbook activity*			×	Learners started out slow in getting the work done and gaining momentum
10	Learners' learning from peers				N/A

Topic: Division

Date: 2017-05-19 Time: 10:30 Class: 6L

Participants: Comparison group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	All learners are working actively on their whiteboards and trying to do examples
2	Game influence on learners' attitude towards working with peers				N/A
3	Learners' motivation to start with the *textbook activity*		×		It is routine to start working individually from their textbook
4	Learners' level of fun while completing the *textbook activity*		×		Learners follow routine procedures to complete the work
5	Learners' engagement with peers (collaboration)				N/A
6	Learners' enjoyment of the *textbook activity*		×		The activity is presented as a list of sums
7	Learners' enjoyment of *working individually*		×		Some learners do enjoy doing division procedures on their own; It involves routine procedures and steps to follow which might be easier for learners to concentrate on their own
8	Learners' development of a love for mathematics		×		
9	Learners' completion of the *textbook activity*		×		While learners are supposed to complete the work, some are chatting in between; This could be due to the difficulty or lengthy operations of division
10	Learners' learning from peers				N/A

Topic: Division

Date: 2017-05-19 Time: 11:10 Class: 6K

Participants: Comparison group

OBSERVATIONS					
NR	**Main observation**	**Poor**	**Average**	**Excellent**	**Comments during observation**
1	Learner's focus when the content is being taught			×	Active learning; Learners work on the teacher's examples by practicing them on their whiteboards
2	Game influence on learners' attitude towards working with peers				N/A
3	Learners' motivation to start with the *textbook activity*		×		Learners know from routine that they are supposed to start with the activity, but instead some learners started chatting
4	Learners' level of fun while completing the *textbook activity*		×		Learners say that if the method is understood, it becomes fun; This could be fun due to learners completing the work quicker
5	Learners' engagement with peers (collaboration)				N/A
6	Learners' enjoyment of the *textbook activity*		×		
7	Learners' enjoyment of *working individually*		×		
8	Learners' development of a love for mathematics		×		Routine work and learners follow operational procedures; Some learners seem to like this topic of work; The textbook offers no extra motivation/excitement/change in routine
9	Learners' completion of the *textbook activity*		×		Learners started slow, but gained momentum
10	Learners' learning from peers				N/A Learners use the teacher as support and bring their work to her to check if they are doing the work correctly

ADDENDUM H: OBSERVATION FINDINGS ORGANISED IN TABLE FORMAT

Topic	Observation number	Experimental group				Comparison group			
		Class	Poor	Average	Excellent	Class	Poor	Average	Excellent
Multiplication	1	6S	0	0	1	6L	0	0	1
	2		0	1	0			N/A	
	3		0	0	1		0	1	0
	4		0	0	1		1	0	0
	5		0	1	0			N/A	
	6		0	0	1		0	1	0
	7		0	1	0		0	1	0
	8		0	0	1		0	0	1
	9		0	0	1		0	0	1
	10		0	0	1			N/A	
	1	6U	0	0	1	6K	0	0	1
	2		0	1	0			N/A	
	3		0	0	1		0	1	0
	4		0	0	1		1	0	0
	5		0	0	1			N/A	
	6		0	0	1		0	1	0
	7		0	0	1		0	1	0
	8		0	0	1		0	0	1
	9		0	0	1		0	0	1
	10		0	0	1			N/A	
		Total	**0**	**4**	**16**	**Total**	**2**	**6**	**6**
		Percentage	**0,00**	**20,00**	**80,00**	**Percentage**	**14,29**	**42,86**	**42,86**
Nets of 3D-objects	1	6S	0	0	1	6L	0	0	1
	2		0	0	1			N/A	
	3		0	0	1		0	1	0
	4		0	0	1		0	1	0
	5		0	1	0			N/A	
	6		0	0	1		0	1	0
	7		0	0	1		0	0	1
	8		0	0	1		0	0	1
	9		0	0	1		0	0	1
	10		0	1	0			N/A	
	1	6U	0	0	1	6K	0	1	0
	2		0	0	1			N/A	
	3		0	0	1		0	1	0
	4		0	0	1		0	1	0
	5		0	0	1			N/A	
	6		0	0	1		0	1	0
	7		0	0	1		0	1	0
	8		0	0	1		0	1	0
	9		0	0	1		0	0	1
	10		0	0	1			N/A	
		Total	**0**	**2**	**18**	**Total**	**0**	**9**	**5**
		Percentage	**0,00**	**10,00**	**90,00**	**Percentage**	**0,00**	**64,29**	**35,71**
Symmetry	1	6S	0	0	1	6L	0	0	1
	2		0	0	1			N/A	
	3		0	0	1		0	1	0
	4		0	0	1		0	1	0
	5		0	0	1			N/A	
	6		0	0	1		0	1	0
	7		0	0	1		0	1	0
	8		0	0	1		0	0	1
	9		0	0	1		0	0	1
	10		0	1	0			N/A	
	1	6U	0	0	1	6K	0	1	0
	2		0	0	1			N/A	
	3		0	0	1		0	1	0
	4		0	0	1		0	1	0
	5		0	0	1			N/A	
	6		0	0	1		0	1	0
	7		0	0	1		0	1	0
	8		0	0	1		0	0	1
	9		0	0	1		0	0	1
	10		0	0	1			N/A	
		Total	**0**	**1**	**19**	**Total**	**0**	**9**	**5**
		Percentage	**0,00**	**5,00**	**95,00**	**Percentage**	**0,00**	**64,29**	**35,71**
Division	1	6S	0	0	1	6L	0	0	1
	2		0	0	1			N/A	
	3		0	0	1		0	1	0
	4		0	0	1		0	1	0
	5		0	0	1			N/A	
	6		0	0	1		0	1	0
	7		0	0	1		0	1	0
	8		0	0	1		0	1	0
	9		0	0	1		0	1	0
	10		0	0	1			N/A	
	1	6U	0	0	1	6K	0	0	1
	2		0	0	1			N/A	
	3		0	0	1		0	1	0
	4		0	0	1		0	1	0
	5		0	0	1			N/A	
	6		0	0	1		0	1	0
	7		0	0	1		0	1	0
	8		0	0	1		0	1	0
	9		0	0	1		0	1	0
	10		0	0	1			N/A	
		Total	**0**	**0**	**20**	**Total**	**0**	**12**	**2**
		Percentage	**0,00**	**0,00**	**100,00**	**Percentage**	**0,00**	**85,71**	**14,29**

ADDENDUM I: SEMI-STRUCTURED INTERVIEW QUESTIONS

1. What role does collaboration have on a learner's development?
2. How does a game-based worksheet influence a learner's engagement with the content?
3. What teaching styles do learners prefer?
4. What learning styles do learners prefer?
5. Do learners focus and listen more carefully when they need the information to be able to play a game? If they do, what influence do you think does it have on their development in mathematics?
6. What elements would you include into a lesson to make it interesting and enjoyable for learners?
7. What is your beliefs and attitude towards using game-based worksheets in the mathematics classroom?
8. How would you describe a quality educational game?
9. What positive influences do you think does game playing have on a learner's development?

Addendum J: Transcripts of the interviews (Translated to English)

Transcript of interview 1 (prior to intervention)

Researcher

Hello, once again, thank you very much. You are welcome to answer in Afrikaans. What role does collaboration have on a learner's development? And when we think about the CAPS, is it "do you have a love for it or a curiosity?" Do you think "collaboration" has a…

Mathematics teacher

With others?

Researcher

Yes, "collaboration" with another child. Could it improve a love for mathematics?

Mathematics teacher

Oh, yes yes yes, it could change the "fun" aspect thereof. Children like to work together, but if you do not group them correctly, two could bring each other down. They will show none, they will show less progress. If you manage it right, it could be fun, you just need to group in the correct way.

Researcher

How does a game-based worksheet influence a learner's engagement with the content?

Mathematics teacher

They basically have more fun, are more enthusiastic because now they want to work. If you just say "take out your books and start with number one", then aaah, it's this part of the work, but I think if you give them a game, then they are more excited and then, they might want to do better, will maybe uhm want to get it right, especially when it, if if a reward is connected, or if competing with each other maybe further say "we got it right, did you also get it right?", because now they are doing it as a group, so that could be “fun” and I think it motivates them.

Researcher

What teaching styles do learners prefer? For example, “engaging”, “active learning”?

Mathematics teacher

Translation: Uhm, these days I like that they don’t help each other, uhm I have a group leader and the groupleader helps the one who’s stuck, so there is engagement, but I I am, I think they sometimes become distracted from what they are supposed to do, uhm, and, I feel they need to be focussed, and then, they would start making jokes and maybe of the, not take the work so seriously, so I avoid, to reach my goal to get through the work and make sure they understand, I would just, let them work individually, I can better see whether they are achieving the success, for example these boards. I started doing it this year, it works for me because they show it and they want to, want to get it right, they want to have their boards up.

Researcher

Yes, “active learning” but with you.

Mathematics teacher

Yes, Yes, not with the friend. I am very “active” with the classes on my own. I am not, but two, they are already in groups which gives a different feeling and not that of “I am sitting in a row”. So that is already the “engagement”. When we do tables, I want it to be “engagement”, but not, not when it comes to understanding the work. Whether it is new work that they need to understand, there is work such as certain work that will lead them to it, such as data. With data they can stand in groups and they gather the information and they do it together, but certain work for me is just, like multiplication, I will not say, “help each other to understand”. It is not to get to an answer, where

I feel I could quickly tell them “yes you have done a lot now, look at this”, thereafter you can decide and say “yes I am going to do what I want”, it’s “fine” with me and then he can help his friend.

Researcher

Yes, I actually found it so in the literature that it says uhm with certain content you can use a game and collaboration. It’s very good that you are saying this. What learning styles do learners prefer?

Mathematics teacher

Oh no “engagement”! They definitely do, but I have to say, I, I notice the way teachers explain will also have an impact on what he chooses. If you have a teacher who only wants to stand on tables and open the textbook and read, that I dislike completely, but a teacher who interacts and walks around. I will, for example, walk around and I will say “you do number a” then I touch your shoulder and you have to answer a. Then I walk to someone else and touch his shoulder and he has to answer. So there, and I must say the children, I think they enjoy the class a lot, so it depends on the teacher what the children prefer and, but obviously fun for a child is always choice number one. Therein I have no doubt. But mathematics is sadly not always fun, you can always make it fun as much as possible, but you cannot spend half the time on fun and the other half on the work.

Researcher

Do learners focus and listen more carefully when they need the information to be able to play a game? If they do, what influence do you think does it have on their development in mathematics?

Mathematics teacher

I think if they, if they play a game they want to make sure, our children like to know how to play a game. They want to know the rules, they want to know what the instructions are, so if they know a game is connected to it, because they always want to, they want to be fair and everyone has to play right and everyone has to play together and follow the rules. So, if they listen better so that it is fair and everyone is on the same plainfield because he wants to achieve success, in contrast to me just saying “you are going to complete an activity after this”, so, but it will mostly be the child who is left behind who will focus better, he wil be the one who focus more, uhm the other one, the stronger child will focus anyway, he will, it won’t have an impact on him, but that child who is definitely the ADHD child who might be up and down and feel that there is a game, “I have to focus now because I want to achieve success and it’s a fun thing”, he will focus more. Think the guy, the stronger guy…

Researcher

Not influenced as much…

Mathematics teacher

No, I don’t believe, he would have anyway.

Researcher

He is actually used to help the weaker guy. What elements would you include into a lesson to make it interesting and enjoyable for learners?

Mathematics teacher

Uhm, the boards, the boards I have noticed works fantastic, because, ug, I have to say out of everything the boards are the most successful because it’s, immediately I can see what the child understands or not. In the past, the child would continue with the work and mark it, you will explain, and he would have started with the books, but now, if the child, he can quickly lift it up without you losing time. Uhm, and and I think we reach more success, but I havn’t really seen another method of play, oh another thing that we also do, if you have plastic, rubber shapes, and you throw the rubber shape to a child and the child grabs the shape, and the one who gets it has to say the name and then throws it to another child and the child who gets it has to say how many faces, so that that that apparatus when you can use apparatus,

apparatus that you can use to make things fun. That is also a nice thing I noticed, uhm, what what playing a game is what it for, they enjoy it a lot, and when they have to build things, toothpicks and and they can eat the jellytot after they built everything if they so, and they get something afterwards, they get something to eat or they get the opportunity to catch a ball, “whatever”, that type of play, to just let a child interact. But not things, other games I will say, the we do group work but more just to pressure each other, it’s not a game.

Researcher

Yes, like competition?

Mathematics teacher

Yes, a healthy competition if it doesn’t help that I force you, then say try another way to force you. Which is horrible to you.

Researcher

What is your beliefs and attitude towards using game-based worksheets in the mathematics classroom?

Mathematics teacher

Ah I think this one I think when I looked at the answer, the crossword puzzle is set up in such a way that the one answer gives a clue for the next one, could kind of help the child, if he is wrong, to immediately realise “I am wring, let me try again”, so if he were to do it in a list, then he will think all six answers are correct and leave it, but now there is a better chance that he can see when he makes a mistake. So, I kind of liked that, that there is something “fun” in the activity that could lead him to correct himself, to lead himself to what is correct or wrong. So that was kind of nice to me that I kind of though, one could use something like this in the future, uhm, give a clue, uhm, that the children could use.

Researcher

Yes, like, yes you can type it in, like on this website, you can type in and then they have a seven or something which they can start with.

Mathematics teacher

So, with regards to that, yes, it was nice to me. I think the marking work, I think to alternate for children, I also realised was important. Don't always "open your books, begin", it's just a lot of writing, I think with regards to that one should actually do something like that just to alternate. Actually, I have to say once a week if it leads to that.

Researcher

My one friend also told me, and that one cannot use this every day because then it will lose its effect, and I never even thought of that, so also what you said once a week for alternation. How would you describe a quality educational game? What should be in a game that is educational?

Mathematics teacher

Uhm, I think the quality is your end goal. If you begin and you say "this is my goal for the end of this period and that game can get you to your goal, then it is a quality game.

Researcher

Like the objectives and things like what is in the CAPS?

Mathematics teacher

Because you, this is why you teach, it is to make sure they master that which is expected of them. So any activity's goal should be to see if they mastered it. So, if that activity can show what it's supposed to master and what I like about the activity, there isn't 20 questions in it, there are a few questions and those questions can test the objective, to see whether they achieved success. So, for me it's about the, to see if the, the skill has been achieved, or or whether it was successful and if it was effective, uhm, I couldn't say exactly what, if there should be pictures, or colourful, uhm, it it doesn't have the impact because of what it looks like physically, but if it if it could be "nice", because if it looks "nice" then it is interesting to the children and then they want to do it. If you just give them a regular crossword puzzle and uhm maybe not, a picture helps, but you, if I just gave a white piece of paper and wrote it myself and it wasn't neat, uhm then they may not have felt that it was that "nice", so how it is structured is also important because it will also help motivate them, to see it's a neat thing so "let's try to work better" to do it neatly, and if it is organised, mathematics to me is an organised subject, so it needs to be well organised which is also important to me. It shouldn't confuse them, they also need to beable to easily understand the activity so that we can reach success.

Researcher

Yes, because one is supposed to learn the content and not a game. What positive influences do you think does game playing have on a learner's development? So, which positive influences, can it be academically, socially, what things?

Mathematics teacher

I would say social, uh, if we look at the AMESA papers and Conquesta that we write, that they may write together, it helps them to think and then I was half surprised how a weak learner has done well together with a strong learner and it wasn't because he was pulled through because of the strong learner, he did his part. So, in a game like that, the weaker child brings, sometimes "shines" a little bit more than you would have thought. So, with regards to some of it, I think social definitely and the academics can mirror what you never would have expected, the results you expected. So, it can also promote acadmics, but it is a fine line. I would say the activity should be put together as 80% goal driven and about 20% for the fun, of 70% goal and 30% fun. I will never make it 50/50, because I think you can easily, if it, let's say, let's talk now, then we need to cut out papers and it's just "fun fun fun fun fun" all the time, then even though you reach your goal, he might not remember. He will remember more fun than really realise what he just did. He's more going through the motions, he goes and talks and that he must not, the the activity must be so that they talk about the work, there must not be opportunity to talk about the weekend because the content isn't engaging enough. So, if it is put together like that it can definitely be academically.

Researcher

Thank you for your time.

Transcript of interview 2 (Post intervention)

Researcher

Hello, thank you for allowing me to interview you. You may also answer in Afrikaans. What role does collaboration have on a learners' development? What you could see now, what you think. What role did collaboration have on their development like in terms of love for mathematics, like the development things in our CAPS document. Uhm, create a curiosity, or such things?

Mathematics teacher

The fatc that they played?

Researcher

Yes, and together through collaboration.

Mathematics teacher

Uhm... Fun, more fun in the classroom. Obiously if you have more fun, a class will be nicer for you. So, uhm, one does not always know if there is learning taking place in total, because you don't have control over it, but for the child it is much more fun and more fun is usually more "it's nice" and more a love…

Researcher

How does a game-based worksheet influence a learner's engagement with the content?

Mathematics teacher

Well, uhm, it has a lot, think they might want to get to the answer more in the end, whereas if you were saying "just carry on" then they might not be as driven to really get to the answer, but now they are more driven to really see "can I get to the answer". It's more a game format.

Researcher

What teaching styles do learners prefer?

Mathematics teacher

Uhm, I noticed, and I spoke to the children. For them it is not only important about the style nie, but about the explanation of the work. A child wants to have the work explained to them, because he wants to know that he understands. So, if he has a game, it's not always necessarily fun if he still does not know what it is. He is, sometimes the children are too lazy even if it is in a game to still think "what I need to do to get to the answer". So, for certain learners it is fun. For a child with insight and it is, but a child who struggled, it wasn't fun for him because he still did not understand the work.

Researcher

What learning styles do learners prefer?

Mathematics teacher

Yes, I would say I think it needs to be a combination, because we just did a practical the other day and the children loved to read scales, but I think it, there has to be a balance. There needs to be games sometimes. Sometimes it needs to be the child discovering on their own, and sometimes the teacher needs to give, and it is important that there be more of a balance, uhm, and not only one style.

Researcher

But which one do you think they prefer?

Mathematics teacher

I think, uhm, I think they want the teacher to do the explaining, because we talked about it and they talked about previous teachers, they started talking about, and then they would say "but this teacher explained and that teacher did not and that was better for us to be explained to more because then we understand the work more, and they prefer to be explained to.

Researcher

Do learners focus and listen more carefully when they need the information to be able to play a game? If they do, what influence do you think does it have on their development in mathematics?

Mathematics teacher

Children listen better when they think it will be for marks. If it's going to be for marks on their reports and I told them it will count, then they definitely listened, but children if they, as soon as they know, that's their main motivation, is it going to count or not. So, as soon as they know it's more a game, they might not be as focused, but as soon as they know it is connected to a reward, whether it is for a dot or to show a mark to his father on his report, then there is definitely more focus. So, it depends on what the end result will be. If it does not make a difference whatsoever then he did not necessarily listen better.

Researcher

What elements would you include into a lesson to make it interesting and enjoyable for learners?

Mathematics teacher

Uhm, I think, liked the game think a lot, I just wish that, I, I, I know these days they say there are certain schools who do not write tests anymore and uhm, and only at high school you start assessing. I thought that would kind of be fantastic if we could learn through play all the time and to discover on their own, but because there is so much time, because one is pressured by the program from the state, you must this, you must that, you must assess this, there is really no space to get this play-play way, because you have to give results and you have to deliver results and take responsibility for those results towards parents, the state, and yourself. So, I would like to say there is a place and space for play, but there isn't. There is no time.

Researcher

Yes, and it would have been a fun practice thing. Say you explained the work one hundred percent, then, then they can do worksheets and actually enjoy it.

Mathematics teacher

Mathematics would be more fun, but uhm, you won't achieve what you want to.

Researcher

What is your beliefs and attitude towards using game-based worksheets in the mathematics classroom?

Mathematics teacher

Ah, I am very open to it, I have to say, I, I wish the focus could be taken a little bit off of assessing all the time, but I am very open to it. If I knew we had the time, but what is nice now is that when we get to the end of a period of time, to see if they understand the work, I would use it more like revision if the time allows it.

Researcher

How would you describe a quality educational game? If you look at these four, was there something "quality" or how would you describe it?

Mathematics teacher

I think there needs to be some challenges, uhm, I think uhm, I think, yes challenges. It shouldn't just uhm, the level, firstly the level for me, it should, it should, in mathematics there is knowledge, discovery, the challenges and the routine. I think if I go back to that I would say it could count much more marks and completed over a longer period of time to involve all four elements, because at this moment it has been more knowledge, but because there were time constraints one cannot assess all four, so next time if I, if I were to take it and do it all over, I would try that the child who is only capable of doing the knowledge, highlight his things, but also a more challenging one. Uhm, I kind of liked your division one, because they had to physically do the work to get to the answers to get the "Bingo" row. The one about matching column A to B, that is, that is a very easy one and the game was completed in a much shorter time. So, the game must be of such nature that I would say it has to have all the levels, and it has to, it cannot be a five-minute game. Unless it functions as an introduction, that can be very nice if you could use such a game as an introduction so that you just need to assess pre-knowledge, then it does not need all the other things. So, it depends on the goal for pre-knowledge, should it only have knowledge based questions. If it wants to test the scope of the work then it needs to include all four aspects. But it is still difficult to set something like that up.

Researcher

What positive influences do you think does game playing have on a learner's development? Did it have a positive influence on them?

Mathematics teacher

Yes, I must say, uhm, I, I think that if the game is put together right, one of the things that I think, what the children struggle with the most, is challenging questions. So, I think that if you, if you have this game, but it is actually focused on the challenging questions like your AMESA questions, your Conquesta questions, and they have to sit together to solve problems, it could be very good to develop these children's brains to do problem solving, because that is what I noticed, it is a big gap in children. The quick knowledge, the matching, the see, that's easy, but I would, I think for problem solving they can start realizing “how can I get to the answer now”. It can make a big, the game in this way can make a big contribution.

Researcher

So, it’s actually academically also and then does it also have an effect on another level?

Mathematics teacher

Yes, because the game need not only be mathematically oriented. It could, it is in mathematics, count the triangles but look outside the borders, how, how, how, what, what it is, it’s a simple example, but I think games can play a very big role more with that one than necessarily with knowledge that needs to be transferred.

Researcher

And a positive influence on their attitude or something towards mathematics? Do you think there are learners who really dislike it?

Mathematics teacher

Yes, I actually don’t think that there was any child that did not like it. I think all the classes would have liked, would have liked the fun part, because uhm, to have fun, to do it in another way is more fun. It was just uhm, it was over too quickly that they would have liked to have fun for a longer time so that they can see that mathematics can also be fun. It is not only mathematics… We just did mass and I told them that, and we did, we did practical work and they realised but what we need to do now will be used in society when he is 30 years old and I think if they have fun, they can see how they are actually going to use mathematics in the future. It is not only about where I sit now, but this one actually helps me to approach it more in this way, which is to me a positive influence then on their futures. Not the now.

Researcher

Thank you very much for your time and participation in my study.