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

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Abstract

This study investigated the developmental influence of collaborative games, in the form of game-based worksheets, on the performance and attitudes of sixth-graders in the mathematics classroom. It is posited that games have the potential to enhance learning through positive emotional experiences. Furthermore, non-digital game based learning methodologies, which forms the focus of our study, are accessible in terms of cost effectiveness, providing opportunities for social interactions while learning, and demanding few prerequisite skills. To this end, this study investigated the opportunities for learning that non-digital, textbook-based game worksheets could afford learners when engaging in mathematical tasks. In this case study, a quasi-experimental design was implemented and pre- and post-tests were conducted before and after an intervention. From a statistical analysis of the test data, using the Mann-Whitney U-test, it was concluded that the intervention had a positive impact on the experimental group of this sample. The experimental group was observed while participating in the games and the observation schedule was member-checked. The Game Object Model provided the framework for designing educational collaborative game-based worksheets used during the intervention. The results indicated that learners benefited from the incorporation of the combination of collaboration and games and that their achievement improved. The findings also suggest that the collaborative games positively influenced learners' developmental areas such as confidence, skills and understanding in mathematics.

Keywords: mathematics classroom, game-based worksheets, collaboration, development

1. Introduction and background

Schooling worldwide adjusts itself according to the dynamic landscape and movement in the political, social, and economic milieus in which countries are situated. As a result, in the early 1990s, several countries started focusing on the implementation of STEM in schools (Williams, 2011; Sanders, 2009). STEM is an acronym for the disciplines of science, technology, engineering and mathematics, which were initially promoted in support of economic dominance. To this end, STEM initiatives have been funded by government authorities and promoted by politicians worldwide as a pathway to vocational and economic goals (Williams, 2011). Mathematics is considered a key subject in STEM education (Li & Schoenfeld, 2019), but a growing negativity towards mathematics raises concern (Goodall, Johnston-Wilder & Russell, 2017).

In considering this negativity, this study was prompted by two concerns. Firstly, according to the Trends in International Mathematics and Science Study (TIMSS), the results from a TIMSS questionnaire item, "I enjoy learning mathematics", revealed that the older learners get, the less they enjoy mathematics, regardless of the fact that learners continue to achieve success in mathematics (Mullis, Martin, Foy & Arora, 2016). Secondly, there seems to be an increase in terms of learner diversity in mathematical readiness, mathematical conceptions, abilities, and interests (Kurtz, 2014; Trinter, Brighten & Moon, 2015). This diversity implies that mathematics education should be responsive to the various different student needs (Vithal, 2012).

One strategy that has been shown to transcend the constraints of diverse student needs in mathematics classrooms is Game Based Learning (Offenholley, 2012; Pramling Samuelsson & Johansson, 2006; Vogt et al., 2018). A Game Based Learning approach holds that games have the potential to enhance learning through positive emotional experiences (Offenholley, 2012). The focus of this study is non-digital game based learning methodologies, which are accessible in terms of cost effectiveness, providing opportunities for social interactions while learning, and demanding few prerequisite skills (Naik, 2014).

To this end, this study investigated the opportunities for learning that non-digital, textbook-based games could afford learners when engaging in mathematical tasks. Incorporating educational games in collaborative environments increases the effectiveness of teaching (Trinter et al., 2015) because differentiated educational games have been shown to support learner achievement in mathematics. Ke and Grabowski (2007) suggest that using educational games in the classroom has a more positive effect on learner performance in examinations than traditional teaching. They also found that the cooperative aspect of game playing in the elementary mathematics classroom was significant in the development of positive attitudes toward mathematics (ibid, 2007). Therefore, the research question which guided this study is: How do collaborative games influence learner development in terms of a positive attitude and improved performance in the mathematics classroom?

2. Rationale

By making use of games, learners learn through their experience by living and doing, which brings about a greater engagement with the mathematical content knowledge (Mayesky, 2009). The rationale behind the research conducted in this study is twofold: firstly, that when learning is enjoyable, learners will stay engaged, thereby increasing their attention, especially when they need the content being taught to be able to participate in a game, and secondly, that collaborative games could potentially influence learners' attitudinal development in mathematics. The significance of this study lies in the fact that the games that were incorporated were created from textbook exercises that did not require specialised knowledge in order to be made. As a result, the games were simple and easily produced. This study aims to contribute to the field of mathematics education in the context of collaborative activities by confirming that collaborative games improve learner achievement, and by showing that making the mathematics classroom more interesting through the incorporation of games is in fact accessible to teachers. If teachers do not find ways of making mathematics more enjoyable and inclusive for learners, the learner negativity towards mathematics to which Goodall, Johnston-Wilder and Russell (2017) refer, may in fact increase.

3. Literature review

Literature supports the incorporation of collaborative games in teaching mathematics (Offenholley, 2012; Pramling Samuelsson & Johansson, 2006; Vogt et al., 2018), albeit with some contrary voices (Bragg, 2012). The use of Game Based Learning has shown improved levels of enjoyment among students (Kurtz, 2014) and improved achievement (Capar & Tarim, 2015). Game Based Learning has the potential to create an environment for active learning that includes elements such as fun, social interaction, motivation, and creativity (Cojocariu & Boghian, 2014).

According to Dockett and Perry (2010), however, Game Based Learning in mathematics does not necessarily guarantee learning, but it can support development in areas such as curiosity, recognising mathematics in social environments, and promoting the relevance of mathematics in everyday lives. In fact, even "one step in learning may actually mean one hundred steps in development" (Bodrova, 1997, p.21). Although mathematical development is not guaranteed through play, there is the potential for play to promote such development (Dockett & Perry, 2010). The development in mathematics focused on in this study refers to development in a critical awareness of mathematical relationships (social, environmental, cultural and economic relations), confidence and competence, curiosity, 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). Chang et al. (2015) conducted a study in which they compared the achievements of learners who completed paper-and-pencil drills, with learners who played a mathematical game. The learners who played the game demonstrated improved performance in mathematics (Chang, Evans, Kim, Norton & Samur, 2015).

Collaborative activities in the mathematics classroom have also been found to improve learner performance. Pareto, Haake, Lindstrom, Sjoden and Gultz (2012) report that the cognitive effects linked to collaborative game playing includes logical reasoning during higher order problem solving and decision making which could, in turn, lead to higher achievement in mathematics. In Chen, Looi, Lin, Shao and Chan's (2012) study, two classes were compared, one class working individually and the other collaboratively, and they found that collaboration assisted learners in mathematical problem solving and enhanced their learning, particularly in low achieving learners. Similarly, in Plass et al.'s (2013) study comparing individual, collaborative and competitive modes of learning, it was found that complex information and mathematical problem solving was better dealt with when learners worked in small groups. It is thus conceivable that learners' conceptual knowledge and problem-solving skills increase when collaborative play has taken place (Capar & Tarim, 2015; Cojocariu & Boghain, 2014; Plass et al., 2013).

Play involves creativity, curiosity, problem posing, and problem solving (Dockett & Perry, 2010). Through play, learners' natural curiosity is awakened, mathematics is recognised as a social activity, and mathematics is related to their everyday lives (Dockett & Perry, 2010). The literature documents further benefits as follows: game-based learning connects learners (Cojocariu & Boghain, 2014); social skills develop when collaboration is incorporated (Pareto et al., 2012); mathematical thinking, such as innovative thinking, risk taking, and problem solving, are supported through social interactions (Dockett & Perry 2010). It has been found that social interaction during play also facilitates joint meaning making when learners test, explain, and share their perspectives and understanding (Dockett & Perry 2010).

Providing learners with the opportunity to play gives them the opportunity to create meaning from their experiences and to scaffold information through interacting with others, especially with more knowledgeable peers (Bodrova, Germeroth & Leong, 2013; Dockett & Perry, 2010). In heterogeneous groups, less able learners benefit by constructing accurate knowledge from the explanations of others (Ter Vrugte et al., 2015). In Chen et al.'s (2012) study, learners played the 'Cross Number Puzzle' game on a computer which also provided game 'tips' when needed. They found that learners from the class who worked collaboratively, relied more on each other than the game 'tips'. However, heterogeneity in the groups could be problematic if the interaction is limited to high achieving learners giving and low achieving learners receiving (Noddings, 1989). Competitiveness may lead to high achieving learners becoming more dominant and low achieving learners' participation decreasing because of increased tension, anxiety, frustration and feelings of inferiority (Ter Vrugte et al., 2015). Generally, though, game-based activities are known to increase learners' enjoyment of mathematics, engender positive attitudes, make the content interesting and foster active engagement in learning (Chen & Law, 2016; Cojocariu & Boghain, 2014; Ramani, Siegler & Hitti, 2012).

In Pareto et al.'s (2010) study, the combination of collaboration and competition was found to contribute towards creativity during game play, as well as full engagement with the subject matter. James, Gerard and Vagt-Traore (2010) found that diversity in groups may in fact foster creativity in learners. At the same time, anxiety and frustration levels are lowered (Katmada, Mavridis & Tsiatsos, 2014; Ke & Grabowski, 2007) as attitudes improve, which in turn may positively impact learners' performance in mathematics (Chang, Evans, Kim, Norton & Samur, 2015).The literature however does not show how textbook based games, simply designed on paper, can also make the kind of difference described above.

4. Conceptual Framework

The Game Object Model (GOM) (See Figure 1), which is based on Object Oriented Programming concepts, was adopted as this study's theoretical framework and used to design quality educational games which are engaging, supporting authentic learning in social contexts, and challenging, as is suggested by Amory, Molomo and Blignaut (2011). The model consists of pedagogical dimensions and game elements that are used to design quality educational computer games (Amory & Seagram, 2003).

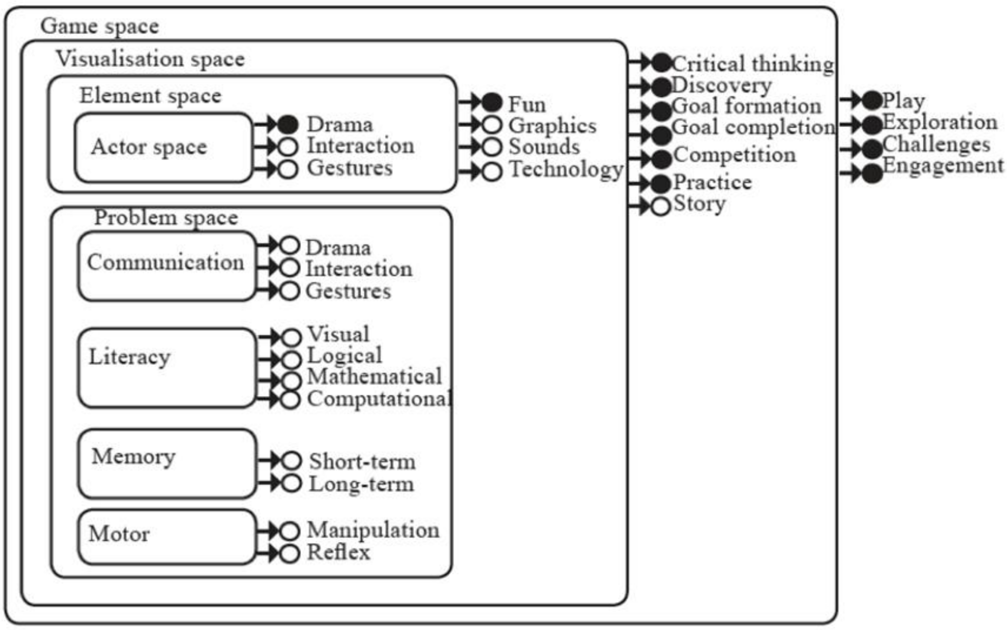

Figure 1. Visualisation of the Game Object Model (redrawn from Amory & Seagram, 2003) (Amory et al, 2011)

According to the GOM model, 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). The game space includes playing, exploration, challenges, and engagement, all of which are motivational abstract attributes. The visualisation space involves critical thinking, discovery, goal formation, goal completion, competition, practise and storyline. The element space denotes fun, graphics, sound, and technology. The actor space includes drama, interaction, and gestures. The problem space involves communication, literacy,, memory, and motor, which link to visualisation attributes like, critical thinking, discovery, goal formation, goal completion, competition, practice and story.

Not all the components of the GOM framework were relevant to this study, since the focus in this study is on games that could be designed by any primary school mathematics teacher: simple, easily designed, textbook based, non-digital games. Specific attributes from the four main space categories were deemed relevant and applicable and could be incorporated into the design of the collaborative game-based worksheets used in this study. The overarching attributes from the general game space in the framework, namely play, exploration, challenges, and engagement, were pursued in the design process. Discovery, goal formation, goal completion, competition, practice (attributes that lie within the visualisation space), fun (lies within the element space), interaction (lies within the communication area of the problem space), visuals, logic, mathematical, computational (attributes that lie within the literacy space), short-term memory, and long-term memory (lie within the memory space). These components and attributes then functioned as the predetermined codes used during the analysis of the data.

5. Method

Game playing, through engagement, falls largely under the Social Constructivist Theory. Constructivism is a paradigm that suggests that knowledge is constructed through experience. The Social Constructivist Theory includes collaboration, which is measured in this study. One of the assumptions of interpretivism lies in the construction of knowledge through the social world (sharing meanings and interaction). So, a social constructivist paradigm allowed us to take a qualitative approach in a quasi-experimental design with existing groups. The numerical data were statistically analysed, but, in the words of Maxwell (2010), “the use of numbers by itself doesn’t make a study ‘mixed methods’” (p. 475). Since this study tested ideas on learners, and data were collected through tests, an intervention and observations, pragmatism was appropriate for the research philosophy of this study.

5.1. Participants

A primary school was conveniently sampled. The Grade 6 mathematics teacher and Grade 6 learners were chosen purposefully to participate in the study because Grade 6 is the gateway grade for leaving the Intermediate Phase (Grades 4-6) and entering the Senior Phase (Grades 7-9), in South Africa. The Grade 6 mathematics teacher had 18 years of experience and she facilitated the intervention herself during the second term of the year. Out of 116 Grade 6 learners, aged 11–12 years, a total of 51 learners (17 male and 34 female) agreed to participate in the intervention while being observed. The quasi-experimental design of the study required the existing Grade 6 classes to be assigned to an experimental group (two classes, 28 participants) and a comparison group (two classes, 23 participants). The experimental group consisted of 10 males and 18 females and the comparison group 7 males and 16 females. All of the participants were required to complete a pre-test and post-test on four different mathematics topics.

5.2. *Materials*

The school's principal, the Grade 6 teacher, Grade 6 learners and their parent(s)/guardian(s) received letters explaining the study and seeking their permission to participate in the study. Data were collected systematically and as objectively as possible through the intervention and observations. Multiple methods were used to improve the study's trustworthiness, and member checking was invited to compensate for subjective observations. Cope (2014) explains that "qualitative research is not inferior research, but a different approach in studying humans. Qualitative research emphasizes exploring individual experiences, describing phenomenon, and developing theory" (p. 89). That is exactly what this study purports to do. Both descriptive and numerical data were collected to provide a deeper understanding.

The intervention covered four mathematics topics: multiplication, nets of 3D-objects, symmetry, and division. Two of the topics, multiplication and division, fall under the content area 'numbers, operations and relationships' in the curriculum (Department of Basic Education, 2011), while the other two topics, nets of 3D-objects and symmetry, fall under 'space and shape' (Department of Basic Education, 2011). The content area 'space and shape' requires skills from the lowest cognitive level in terms of the South African curriculum specifications, described in the curriculum as 'knowledge', involving "estimation and appropriate rounding off of numbers; straight recall; identification and direct use of the correct formula; use of mathematical facts; appropriate use of mathematical vocabulary" (Department of Basic Education, 2011, p. 296). The content area 'Numbers, operations and relationships', requires skills from the second cognitive level, 'routine procedures', 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 the correct formula generally similar to those encountered in class" (Department of Basic Education, 2011, p. 296). To accommodate the four content areas, four pre-tests and four post-tests were designed. Learners completed one pre-test and a post-test per week of the intervention e.g. Week 1: pre-test on multiplication and post-test on multiplication.

The pre-tests consisted of existing knowledge questions involving content learnt in the previous year (Grade 5) and taken from the Grade 5 mathematics textbook. The post-tests consisted of questions taken from the Grade 6 mathematics textbook, the specific content of which was covered during that week, testing new knowledge. Both the experimental group and comparison group completed the same questions for the post-tests, but in different formats (textbook and game-based worksheets). The comparison group completed the questions from the Grade 6 mathematics textbook as they normally would, while the experimental group completed the same questions, but designed in an educational game-based worksheet format.

Observation schedules were used to observe both the experimental and comparison group only during the completion of the four post-tests. The observation schedule consisted of criteria based on the attributes provided by the theoretical framework of the study. Each observation was measured as either poor, average or excellent, and recorded on the observation schedule and further in an Excel spreadsheet. Each group consisted of two classes, therefore during each of the four Fridays (four mathematics topics), two classes were observed, yielding a total of eight observation opportunities per group.

5.3. Procedure

The study's quasi-experimental design made use of existing groups (classes) for the intervention. In this school, learners are randomly assigned each year into classes for the following year by a computer system, which ensures some degree of randomisation for the intervention, thereby enhancing the objectivity of the study. Of the four existing Grade 6 classes, two classes were randomly assigned to the experimental group, and the other two classes to the comparison group.

The intervention took place in Term 2 for a total of four weeks. Each week, one of four mathematics topics was covered. For the intervention, the teacher taught her classes as she normally would, with the addition of the pre-tests and post-tests. Both the experimental and comparison groups completed the same pre-test at the beginning of each week before the topic of that week was covered. A post-test was completed every Friday after that week's topic was covered. On the Friday, learners were observed for the duration of the whole lesson, including while the content was being taught and the post-tests were being completed. Participating learners' marks were recorded on class lists and later typed into an Excel spreadsheet for analysis. The data were organised in table format where formulae were used to calculate averages and differences between the two groups, as well as to generate graphs from the data.

Observations of learners' focus, attitude, motivation, level of fun, level of collaboration with peers, enjoyment of collaborating, enjoyment of the game-based worksheet/textbook, and completion of the game-based worksheet/textbook were made. Observations were made from the back of the class to limit influence on learners' behaviour. The teacher was able to confirm the observations made since she was teaching the classes. The 16 observation schedules' data were recorded into an Excel spreadsheet where it was possible to calculate the average that each measure appeared for both groups respectively, as well as to create pie graphs that visually present these averages.

6. Results

6.1. The pre-test and post-tests

The pre-test-post-test design used in the intervention provided numerical data, which were used to support the qualitative findings from the observations. The data from the tests were statistically analysed. In this study, the sample was divided into two groups: the first group represents the cohort of which the experimental game instruments were used and the second group is the comparison group.

Given that the distribution of the data was not normal and the sample size was small the Mann-Whitney U-test was selected to determine if a statistically significant difference exists between the two independent groups. The null hypothesis stated that there is no tendency for the ranks of the experimental group to be significantly higher or lower than the comparison group. The research hypothesis stated that the ranks of the experimental group are systematically higher or lower than those of the comparison group. Group 1 in Table 1 represents the experimental group. Based on the results in the multiplication category, we reject the null hypothesis in favour of the research hypothesis if we set a 10% level of significance. We also see that the intervention has had a positive impact on the learners' performance. The results in the nets of 3D objects category show a positive impact in the learners' ability to exercise this kind of skill. However it is not statistically significant and therefore we could not reject the null hypothesis. With respect to the topic, symmetry, we found that it has had a slightly negative impact on learners' ability, however this was not statistically significant. In the division category we see that there was a notable positive impact in the ranks of the experimental group and therefore we reject the null hypothesis in favour of the research hypothesis at a 1% significance level. Overall, it would seem from the available data that the intervention had a positive impact on the experimental group of this sample.

Table 1. Results of the Mann-Whitney U-test

Ranks

Group		N	Mean Rank	Sum of Ranks
MULTIPLICATION	1.0	25	27.74	693.50
	2.0	23	20.98	482.50
	Total	48		
NETS OF 3D-OBJECTS	1.0	27	24.13	651.50
	2.0	20	23.83	476.50
	Total	47		
SYMMETRY	1.0	26	21.60	561.50
	2.0	22	27.93	614.50
	Total	48		
DIVISION	1.0	28	31.36	878.00
	2.0	22	18.05	397.00
	Total	50		

Test Statistics[a]

	MULTIPLICATION	NETS OF 3D-OBJECTS	SYMMETRY	DIVISION
Mann-Whitney U	206.500	266.500	210.500	144.000
Wilcoxon W	482.500	476.500	561.500	397.000
Z	-1.726	-.215	-1.609	-3.898
Asymp. Sig. (2-tailed)	.084	.829	.108	.000

a. Grouping Variable: Group

Table 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

Table 2 presents the pre-test-post-test results. Of particular significance is the fact that the experimental group scored 1.39% higher in the four pre-tests, and 5.67% higher in the four post-tests. Both groups increased in every mathematics topic between the pre-tests and post-tests.

Table 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 experimental group increased by 13,85%, while the comparison group increased by 9,57%. See Table 3. Thus, the experimental group increased by 4,28% (13,85–9,57) more than the comparison group. The experimental group's highest increase was scored in division (24,11%), and the comparison group in symmetry (14,5%). 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.

The line graph in Figure 2 presents the experimental group (darker line) the comparison group (lighter line). Each group's four pre-tests and four post-tests' averages were combined into one pre-test and one post-test average for each group. The experimental group started off with a 1,39% higher pre-test average, and ended up with a 4,28% higher post-test average. A visual representation of these results is given in Figure 2 in which the gradient of each of the two lines makes it easier to see the experimental group's higher increase than the comparison group in their achievement.

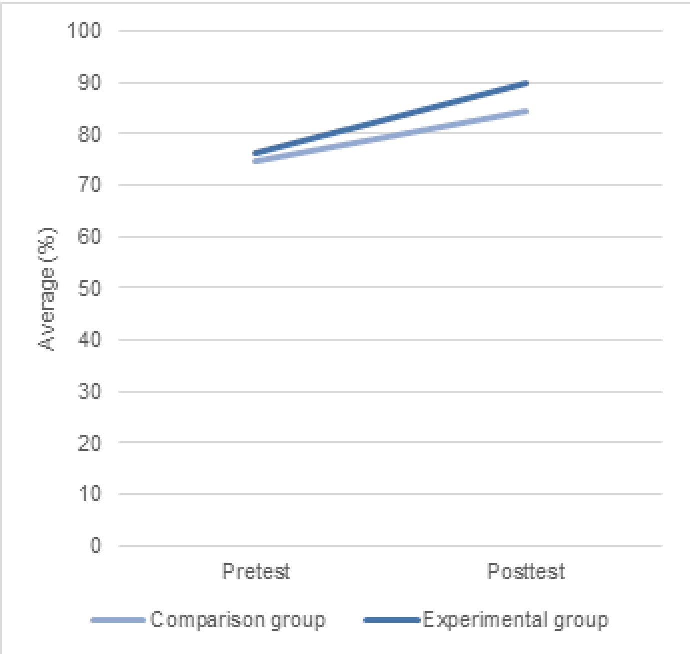

Figure 2. Overall pre-test and post-test average percentages between the experimental group and comparison group

6.2. The observations

The observations were analysed and interpreted using the predetermined (a priori) codes (attributes) from the theoretical framework. These attributes were designed into the game-based worksheets. Attributes from the conceptual framework were condensed into ten observation criteria: (1) Learner's focus when the content is being taught; (2) Game influence on learners' attitude towards working with peers; (3) Learners' motivation to start with the textbook activity; (4) Learners' level of fun while completing the textbook activity; (5) Learners' engagement with peers (collaboration); (6) Learners' enjoyment of the textbook activity; (7) Learners' enjoyment of working individually; (8) Learners' development of a love for mathematics; (9) Learners' completion of the textbook activity; (10) Learners' learning from peers. The same observation schedule was used for the experimental and the comparison group, but the comparison group was not observed for observation numbers 2, 5, and 10, (as seen in the Table 4) because these three observations pertain only to the experimental group since they dealt with collaboration. Observation criteria 3, 4, 6 and 9 used the words 'game-based activity' for the experimental group, and 'textbook activity' for the comparison group. Each group was observed a total of eight times during the intervention period (two classes per group across four topics). Therefore the total that each observation number could be observed as 'poor', 'average', or 'excellent' was eight times.

Table 4. Summarised frequency distribution for each observation

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

The teacher was asked to check the measures that were allocated to the ten observation criteria - she concurred with all of them. The experimental group's most frequent measure of all the observations was excellent, while the comparison group's was average. This may be interpreted to mean that learners tend to function more at an 'average' than at an 'excellent' level while following a routine and working from their textbooks. Out of the eight observations, almost all of the experimental group's average measures were on "game influence on learners' attitude towards working with peers", "learners' engagement with peers", and "learners' learning from peers". The theme of these three observations was collaboration. Although 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. However, when help was needed, they asked for help and learned from each other, checking 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.

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 experimental group completed the game-based worksheets very quickly. This was partly due to their understanding of the content because they were more focused during the teaching of the content: they knew they needed to be able to do the work in order to participate in a game. Enjoyment, fun, excitement, motivation, and enthusiasm were observed during the implementation and completion of the game-based worksheets by the experimental group, but could not be observed in the activities of the comparison group. In fact, the comparison groups demonstrated a distinct lack of motivation to get started on their textbook activities. The 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. When the teacher introduced the game-based worksheet to the experimental group, their first reaction was yelling out "yes". Once the learners received their game sheets, they immediately started to cut the worksheet out and paste it into their workbooks. They also signalled to their peers with whom they were grouped, to come and sit with them. Some learners even started their game sheets by saying, "1, 2, 3, start!"

By 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.

7. Discussion

The experimental group was most positively affected in terms of learners' focus, attitude, motivation, level of fun, engagement, enjoyment, collaboration, love for mathematics, completion of the work, and learning from peers, through the collaborative game-based worksheets, as concluded from the observation findings. Since collaborative game-based worksheets are not prescribed by the curriculum or part of everyday teaching and learning, the introduction thereof may have influenced learners to participate at an excellent level. The findings from the observations showed that the experimental group was measured average on the theme of collaboration, while being observed as excellent on the other observations, concerning the theme of enjoyment and fun. This finding may be explained by high achieving learners preferring to work individually, but also that the game-based worksheets brought fun and enjoyment into the classroom.

According to Pareto et al (2012), learners' higher achievement is due to the cognitive effects of collaboration: higher order problem solving and decision making. The experimental group had the highest increase in the post-test averages in multiplication and division, which require skills from a higher cognitive level than the cognitive level required for nets of 3D-objects and symmetry. Thus, this study shows that collaborative game-based worksheets are beneficial when learners need to develop routine procedures skills such as performing well-known procedures, solving well-defined problems, applications and calculations, obtaining information, identification and use of formulas (Department of Basic Education, 2011). The results from the intervention showed that both groups experienced an increase in each mathematics topic between their pre-tests and post-tests. Thus, in both formats in which the work was completed, learners were able to develop and achieve success, but the introduction of fun and collaboration made the difference.

Simply put, the learners enjoyed completing a collaborative game-based worksheet more than working from the textbook as they usually would have done. Secondly, it became clear that when learning is enjoyable, learners engage with the content and pay attention in order to be able to participate in a game. Lastly, it was shown that the positive influences of the combination of collaboration (support) and the game-based worksheets (fun) on learners' development in mathematics resulted in higher achievement in mathematics.

Limitations of the study include a lack of randomisation resulting from the use of pre-existing classes. Nevertheless, some degree of randomisation was implemented in assigning classes to either the experimental group or comparison group. Subjectivity was a concern during the observations, but could be confirmed by the teacher (member checking) as she was also present in the classroom. Each group was observed eight times which was an attempt to achieve more accurate averages for the three measures, instead of only observing once.

8. Conclusions

In this study it was confirmed that educational purpose can be designed into game-based worksheets, by using the textbook that the school or Education Department requires. Game-based worksheets should supplement the content, for example, in the form of an introduction or revision in a mathematics topic (Ramani & Eason, 2015). Two of the four game-based worksheets included small clues, such as indicating that multiplication or division was required to solve a particular puzzle. Trinter et al. (2015) suggest that low achieving learners find support in game clues in differentiated educational games. Chen and Law (2016) found that learners apply synthesis, analysis, evaluation, and critical thinking during game-based learning, which was confirmed in this study when learners realised that they had made a mistake and needed to correct it before they could continue and finish the game. The game-based worksheet led to learners experiencing success and enjoyment, and their consistent enthusiasm possibly speaks of confidence and a sense of competence. According to Ke and Grabowski (2007), group learning offers additional help which eliminates frustration.

Mathematics is generally viewed as a gateway subject for STEM- related careers. This view emphasises the need and responsibility for teachers to produce learners that are capable of passing mathematics at all levels of schooling. In this regard, we explored the developmental influence of collaborative mathematics games in Grade 6. This study confirms existing theory on educational games, collaboration, and how these have a positive effect on development in mathematics. This is in direct contrast to the findings of Bragg (2012), who researched the incorporation of games into the mathematics classroom, but with the addition of teacher-led whole class discussion. It may be speculated that this kind of discussion brought about a negation of the effect of the games. This study adds to knowledge in this area by showing that creating and using games in the classroom are not only beneficial, but accessible to any teacher. Expensive technology and knowledge of apps and programming is not a requirement: textbook exercises can be used to create games that may lead to the same potential successes as more complex and expensive games may do. Thus teachers and learners in resource constrained environments could experience the benefits of incorporating games on learners' development in mathematics, especially for low achieving learners.

Recommendations for future research would be to explore learner development in mathematics in different content areas to determine in which content area learners' achievement improves the most through game incorporation in the classroom. This would help identify which approach to use for each content area, for example, individually or collaboratively. More research on how to accurately measure each developmental area will also lead to identifying the influences of collaborative mathematics games more accurately.

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