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EXPLORING GAMIFICATION FOR REINFORCING GEOMETRICAL CONCEPTS AND SKILLS AT THE PRIMARY LEVEL IN TRINIDAD: A Mixed Methods Pilot Study

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Though games have had popular use in primary schools over time, there is increased interest in using elements of gaming in the classroom to promote motivation and thinking skills. This paper reports on a mixed methods intervention pilot study in one primary school in Trinidad that explored the effects of a gamified classroom on reinforcing geometric concepts and skills. Familiar learning tools, like tangrams and origami, were used. A non-equivalent control group mixed method design was used with both groups taking the pre- and post-tests. Only the experimental group used the gamified activities. Qualitative data were obtained from the experimental group teacher's interview and observational notes, and analysed to reveal three interpretive themes about students' perspectives: favourable, unfavourable and change. Overall, students reported that games made mathematics easier to remember. The teacher reported high student engagement, collaborative problem solving, and respectful competition among teams. Quantitative data were obtained from a pre/post achievement test. Analyses reveal significant differences in the experimental group's pre-test and post-test scores. Results from the pilot study were instrumental in developing the gamification approach for the larger study of 10 primary schools.

Introduction

Competence in mathematics is a global educational imperative for societal advancement; however, many perceive mathematics as complicated and tedious. Teachers struggle to make mathematics palatable to learners and even indicate a reluctance to teach certain mathematical concepts (Jaggernauth & Jameson-Charles, 2015). Geometry is one area of mathematics with which students often struggle (Ozerem, 2012). The study of geometry develops students' spatial ability and logical reasoning (French, 2004), and the ability to solve real-world problems in which geometrical terminology and properties occur (Jones & Mooney, 2003). Idris (2007) suggested that students' struggles can be associated with their cognitive development and the instruction they receive in geometry. Consequently, there is a need for teachers to vary instruction in geometry to promote interest and satisfaction in learning, and for students to attain higher levels of thinking to facilitate problem-solving. A specific focus on building students' manipulation of objects in 2-dimensions (2D) and 3-dimensions (3D) can help them to develop greater spatial sense and improve geometric thinking overall. There is an overarching need to develop geometric foundational concepts for the further study of geometry. Therefore, teachers must align instruction not only with what interests students but with students' level of geometric thinking (Ozerem, 2012; van Heile, 1999), to move them from concrete representations to abstract concepts.

Background

One of the goals of the Trinidad and Tobago primary school mathematics curriculum is that students "exhibit the satisfaction that accrues from engagement in learning" (Ministry of Education, 2013, p. 17). The mathematics curriculum guide further suggests that teachers employ "a variety of student-centred teaching techniques and strategies, such that improvement in student motivation and performance will increase in the medium and long terms" (MoE, 2013, p. 22). Geometry is one of four content strands in the curriculum; students are expected to have developed "spatial sense through exploration of solids and plane shapes (MoE, 2013, p.251) … [and] develop appropriate vocabulary associated with geometry" (MoE, 2013, p. 252). In Trinidad, as in other educational contexts, instruction in geometry in primary schools tends to focus on plane geometry (Siew & Abdullah, 2012), neglecting the teaching of manipulation and spatial exploration of 2D and 3D shapes to develop spatial concepts linked to mathematics and other school subjects like art, science, social studies, and music (Copely, 2000).

The use of active learning strategies and teaching aids provides concrete experiences that bridge abstract geometric concepts and concrete geometric objects (Kamina & Iyer, 2009), allowing students to visualise and analyse geometric shapes and develop their geometric thinking. Integrating meaningful activities that use shape models, captures students' imagination and develops their understanding of geometric concepts, reinforces their spatial perception, and contributes to their success in learning geometry (Russell & Bologna, 1982).

According to Ernest (1986), theorists like Piaget, Bruner and Dienes suggest that active engagement is critical for facilitating learning, particularly in mathematics. Findings from this study can help to address the gap in primary student engagement in geometrical learning which is articulated as an educational outcome of the National mathematics curriculum.

Teachers can develop their students' geometric skills through the use of tangrams (Siew, Chong, & Abdullah, 2013) and origami (Brady, 2008) manipulatives. The benefits of using manipulatives in the classroom have been noted (Boggan, Harper, & Whitmire, 2010), and incorporating geometric manipulatives in a game setting allows teachers to combine the benefits of games and manipulatives as learning tools in the mathematics classroom. Mathematics teachers have long incorporated games in the classroom for fun, fostering cooperative learning, active engagement and motivation (Ernest, 1986). The use of manipulatives and games as learning tools had been the focus of primary teacher professional development (PD) in Trinidad and Tobago from period 2002 to 2006 (Khan & Kamalodeen, 2015), and continued teacher PD is necessary to update teachers' instructional strategies.

This paper reports on a study of a game-based learning approach referred to as gamification, which is "the use of game-based elements such as mechanics, aesthetics, and game thinking in non-game contexts, aimed at engaging people, motivating action, enhancing learning, and solving problems" (de Sousa Borges, Durelli, Reis, & Isotoni, 2014, p. 216). It can include digital games but can also refer to gamifying certain elements of a lesson or the environment, as games and game design are themselves "transmedial categories" (Deterding, Dixon, Khaled, & Nacke, 2011). Transmedial categories can include gaming platforms, novels and films, according to Klastrup and Tosca (2004). In this study, gamified tangram and origami activities will be utilised. Gamification is a way to incorporate gaming elements of fun and competition in the learning environment, yet there are insufficient studies that address the success of gamifying mathematical classrooms in Trinidad and the Caribbean.

The Problem

Research suggests that there is a lack of focus on the teaching of geometry for building spatial reasoning in students (National Council of Teachers of Mathematics [NCTM], 2006). Oberdorf and Taylor-Cox (1999) suggested that the paucity of authentic learning experiences in primary school is one reason for students' misunderstanding and misconceptions of geometrical ideas. While geometry instruction must pay attention to fundamental geometrical concepts, students need to be challenged in their thinking for a "balance between enrichment and acceleration" (p. 345).

Tangram and origami puzzles are manipulatives that provide students with opportunities to build spatial reasoning and reinforce geometrical concepts, satisfying essential Mathematics goals of the Trinidad and Tobago curriculum. Consequently, these were selected for gamification to increase students' exposure to authentic learning experiences in one Standard Five level (Grade 6) at a primary school in Trinidad and Tobago.

The use of games as learning tools and students' experiences with games in the geometry classroom are under-researched in Trinidad and Tobago, particularly at the primary level. This study, then, responds to Bragg's (2012) call for research on the effectiveness of games as a learning tool for teaching mathematics, as well as the exploration of the effects and benefits of gamification in school settings (Kickmeier-Rust, Hillemann, & Albert, 2014). It was hypothesised that if students are engaged in learning using manipulative tools in a game setting, there could be a change in academic performance in geometry. This mixed methods study acts a forerunner to a larger study in 10 primary schools in the same educational district and seeks to investigate the effects of gamification in a primary classroom where tangram and origami were used as learning tools for geometry.

Literature Review

Developing geometric thinking

Through the study of geometry, students begin to develop their understanding of geometric structures and their characteristics and relationships, as well as their geometric thinking. Geometric thinking encompasses spatial and logical thinking as related to space and shape, and is linked to spatial visualisation, measurement, and algebra (Kaygorodtseva, 2014). Sinclair and Bruce (2015) suggested that developing spatial thinking improves students' performance in Science, Technology, Engineering and Mathematics (STEM) and provides children with equitable access to mathematical success and learning. Children's success in geometry not only requires mastery of basic geometry facts and ideas about form, magnitude and relative position on a plane and in space (Dedovets, 2001), it also requires instruction that allows them to visualise, think and make accurate conclusions about geometric ideas (Abdullah & Zakaria, 2012), bridging sensory experiences and abstract understanding (Ojose &

Sexton, 2009). van Hiele (1999) suggested that students' progress through five sequential levels of geometric thinking from concrete to abstract (visualisation, analysis, abstraction, deduction, rigour), moving on to the next level, only upon achieving mastery in the current one. Spear (1993) suggested that primary school students engage in thinking within van Hiele's first three levels; young students move from first being able to identify and name shapes without using their properties but based on their real-life experiences at Level 0, to identifying, describing and explaining the properties of shapes in Level 1, and then to describing the properties of shapes and logically classifying them at Level 2 (Costa, Matos, & E-Silva, 2009; Ozerem, 2012). The use of manipulatives in teaching geometry, then, allows students to manipulate concrete objects that can be touched, moved, flipped and rearranged (Ojose & Sexton, 2009), engaging them in hands-on activities during mathematics instruction (Boggan et al., 2010). Children gravitate to play with shapes in puzzles and blocks. Their natural observation of shapes in objects around them supports the use of physical manipulation of geometrical shapes (Lee, Autry, Fox, & Williams, 2008; Tchoshanov, 2011), to develop their understanding of shape and space, and their spatial sense (Clements & McMillen, 1996). Consequently, manipulatives that allow for tactile learning can support children's development of geometric thinking.

Tangrams and Origami as learning tools

Maschietto and Trouche (2010) conducted a review of the historical and recent literature on learning tools, including the theory and practice that support the use of tools to enhance learning in mathematics. They concluded that learning tools in mathematics can emerge from human experience and are used to aid human activity. Further, tools are diverse and can be digital and non-digital. Tools can be derived from already existing materials or be created. They can be used individually or in combination. In conclusion, Maschietto and Trouche (2010) contended that learning tools are pedagogical aids that can be used practically for assisting students to construct mathematical meaning and understanding.

Tangrams. This seven-piece Chinese puzzle can be used to make various shapes by arranging the pieces in different ways, without the constraint of a single solution like regular jigsaw puzzles. Tangrams provide concrete experiences that allow students to compare and categorise the pieces (called tans) and use their properties to solve tangram puzzles. They engage students' imagination and develop their geometry vocabulary; skills in shape identification, classification and orientation; understanding of basic geometric concepts and relationships; spatial sense in the world around them (Bohning &

Althouse, 1997; Lin, Shao, Wong, & Niramitranon, 2011; Yang & Chen, 2010); and analytical, creative, and logical thinking (Russell & Bologna, 1982; Siew et al., 2013; Yang & Chen, 2010). Thus, students learn geometry concepts and relationships in ways that improve their task performance and decision making (Gal & Lew, 2008).

Origami. This Japanese art of paper folding is spatial in nature and engages the visual-spatial modalities of listening, observing, and doing (Boakes, 2009). In the mathematics classroom, paper folding provides tactile experiences that actively involve students in transforming a 2D sheet of paper into a 3D physical model (Cakmak, Isiksal, & Koc, 2014). Brady (2008) opined that paper-folding activities, like origami, develop students' "mathematical ideas, thinking and concepts; skills in communicating mathematically; and group interaction skills" (p. 77). In Boakes' (2009) study of middle school US students, she reported that students found origami activities were "fun" and "enjoyable" (p. 8). Students also reported that it helped them understand geometry. These results are consistent with those of Cakmak et al. (2014) who reported that origami helped Turkish students feel relaxed during learning and developed their psychomotor skills, imagination, creativity and intelligence. Although students experienced some difficulties with the novel strategy, their collaboration led to success in model building. However, Boakes (2009) reported that although a number of studies have linked origami to developing students' visual skills, lamentably, the paucity of research about origami for developing students' spatial thinking is evident. A similar gap exists in the Trinidad and Tobago context.

Games as Learning Tools

Play and games are increasingly endorsed to stimulate dull mathematics classes in the developed and the developing world (Nkopodi & Mosimege, 2009). However, play and games are not equivalent. Games, unlike play, are governed by a particular set of rules to foster competition and can help learners develop mathematical skills while increasing their interest and motivation (Bragg, 2007). Games promote experiential learning that is situated in active play in the classroom. They "promote social skills, stimulate mathematical discussion, develop new strategies and reinforce new concepts and competencies in learners" (Oldfield, 1991, p. 41) at all educational levels. Games transfer motivational elements to learning activities that develop skills of communication, sharing, goal-setting (Landers & Callan, 2011), engagement, interactivity and problem-solving (Ernest, 1986; Kapp, 2012). Bright, Harvey, and Wheeler (as cited in Ernest, 1986) reported considerable gains in the achievement of early secondary school students through game-play. Playing games develops children's strategic and visual thinking skills by training them to pay attention to detail (Dedovets, 2001). It supports the academic environment as a classroom intervention through the non-threatening form of assessment (Wiersum, 2012). It encourages strategic mathematical thinking as students find different strategies for solving problems, and it deepens their understanding of numbers, building fluency through meaningful practice, resulting in academic improvement (Rutherford, 2015).

Conversely, games are not always considered to be a serious learning tool and may even be considered as time wasting (Swan & Marshall, 2009). Bragg's (2012) work with Australian primary students concluded that the use of games did not result in a significant improvement in mathematics learning. Kapp (2012) suggested that individuals are more interested in playing games for the sense of mastery and overcoming challenges and obstacles, and for the social interaction, rather than for external rewards such as points. Shute, Rieber, and Van Eck (2011) proposed, however, that games can support and contribute to learning, but what is needed is more research on the use of games as a learning tool in classrooms through experimental studies. This need exists in the Caribbean also.

A learning game is "a form of participatory, or interactive, entertainment" (Rollings & Adams, cited by Glover, 2013, p. 1999) that comprises "a self-contained unit with a definitive start, gameplay and ending" (Kapp, 2012, p. 44). Typically, a game ends in victory for single or groups of players, with some external rewards. Teachers often use these rewards to motivate and engage students in learning to improve academic achievement and develop appropriate behaviours (Hoffmann, Huff, Patterson, & Nietfeld, 2009). In addition to being enjoyable and fun, well-designed learning games provide students with much continuous and immediate feedback for improvement and, according to Barab, Gresalfi, and Ingram-Goble (2010), allow them to complete tasks that may be too complex for them to do on their own.

The utility of games as learning tools requires students to be engaged in the learning of content during play so they use their knowledge to solve meaningful problems, in an environment supported by clear instructions and feedback, and instructional support from teachers (Hays, 2005). Despite any suggested challenges involved with game play, the potential for learning games to increase student engagement and contribute to improved academic achievement is what fuelled its use in this local study.

Gamification in Mathematics

Mathematics teachers have been experiencing difficulty with low student engagement and motivation to engage in active learning (Huang & Soman, 2013). Engagement, according to Deater-Deckard, Chang, and Evans (2013), is "a collection of mindfully goal-directed states in which motivation arising from positive emotions serves to grab and sustain the learner's cognitive and motor competencies" (p. 22). Engaged students demonstrate their involvement in learning through their behaviour, enthusiasm, optimism, curiosity and interest (Rozendaal, Braat, & Wensveen, 2010). Arnold (2014) suggested that incorporating game-like elements into mathematics instruction can enhance student learning, not by making learning into a game but by enticing students into playing the game, by incorporating game-like features that spark curiosity, encourage exploration and the notion of domination.

Gamification in education refers to the integration of principles and elements of games into non-game activities (Deterding et al., 2011) to "engage [individuals], motivate actions, to promote learning, and solve problems" (Kapp, 2012, p. 10). Although gamification was first associated with the digital media industry in 2008, its use has extended to education, including the use of both digital and non-digital games (Deterding et al., 2011). Gamification has been associated with improving students' motivation, achievement and attitudes toward learning (de Sousa Borges et al., 2014; González, Mora, & Toledo, 2014; Huang & Soman, 2013; Yildirim, 2017); skills reinforcement that improves performance (de Sousa Borges et al., 2014; Preist & Jones, 2015); and attitude and behaviour change in students and teachers (Schoech, Boyas, Black, & Elias-Lambert, 2013).

Huang and Soman (2013) proposed a five-step gamification process that was used in this study. According to this model, the teacher must be familiar with her/his student, their needs and learning preferences, within the context of the specific classroom and school, and the content to be learned during a period of instruction. Then, the teacher must identify and clearly define the objectives and outcomes of the learning experience, before planning instruction. Only then can the teacher decompose the learning content into manageable chunks and sequence them in logical stages of increased difficulty and complexity, and provide opportunities for multiple tries, if necessary, and multiple pathways to task completion. The teacher can then determine which stages will be gamified, identify resources for gamification, develop rules of engagement and identify feedback strategies to track student progress, and for students to track their own progress, and identify and attend to areas for improvement. The process ends with the teacher determining the game mechanics to adopt to focus activities on learning and competing with the self, and with others. Huang and Soman (2013) cautioned that gamification focuses on applying game-like elements to behaviour, rather than outcomes, to achieve objectives by incentivising mundane learning processes.

Perspectives on Gamification in the Classroom

Cheong, Filippou, and Cheong (2014) obtained perspectives from 51 undergraduate students on game elements used in gamification, utilising a questionnaire prior to attempting the creation of a game-like learning environment. More than 90% of the students surveyed opined that they expected gamification to enhance the learning environment and increase their interest in learning, as well as improve their understanding of content. All the students surveyed rated highly their interest in the use of game elements to promote learning in the classroom. Papp’s (2017) study of the effects of gamification on motivation and learning, involved the use of non-digital mathematics games to teach multiplication to two Grade 4 mathematics classes over one school term. Papp (2017) assessed improvement in learning using a pre-test and post-test on multiplication, and gathered students’ perspectives on their experiences in the gamified classroom using focus group interviews and a five-point Likert scale survey. The findings suggested that students improved in their multiplication skills and appeared to be more engaged and more willing to participate in the gamified intervention. Lower-performing students demonstrated greater gains in improvement using the gamified approach. The survey data from the study showed that 80% of students reported enjoying learning, and 90% reported a better understanding of multiplication using the gamified intervention. Students found the gamified intervention to be fun and assisted them with learning in a non-stressful environment. They clamoured for the use of more gamification in the mathematics classroom.

According to Sanchez Mena and Marti Parreno (2017), little is known about what teachers perceive facilitates or hinders the use of gamification in their classroom, despite increasing research on gamification itself. They interviewed 16 higher education teachers who had attempted gamification at least once in their courses. The teachers indicated that drivers for the continued use of gamification were the increases in students’ motivation and attention during gamified lessons, which stimulated learning through active engagement and social interaction while having fun. However, they also found that teachers were reluctant to continue employing gamification because of a lack of time, materials, training and support, as well as their perceptions that students would not be interested in learning through gamification, the difficulty of matching gamified activities to the content and schedule for teaching, and the challenge of managing the classroom when gamification is utilised.

In summary, these findings emphasise the need for further research into the use of games as learning tools in diverse contexts. This study responds to this identified need, and highlights students' and teachers' attitudes to the use of games, as well as learning outcomes in geometry as stipulated in the Trinidad and Tobago Primary Mathematics Curriculum.

Research Questions

This study explored the effects of gamification on student learning in the primary school mathematics classroom through three questions:

1. What were students' perspectives on gamified tangram and origami activities as learning tools in geometry?
2. What changes were observed in student achievement in geometry after exposure to gamified tangram and origami activities?
3. What was the teacher's perspective on gamified tangram and origami activities as learning tools in geometry?

The Mixed Methods Research Design

There is increased use of mixed methods in the study of social and human behaviours. Johnson, Onwuegbuzie, and Turner (2007) contend that this methodological approach can enhance and improve findings related to answering research questions in a single study. The specific benefits of the design in the present study were for triangulation of results (Greene, Caracelli, & Graham, 1989) and significance enhancement (Collins, Onwuegbuzie, & Sutton, 2006) of the mixed findings.

This study utilised a non-equivalent control group mixed method design (Sousa, Driessnack, & Mendez, 2007) that exposed one class to the intervention and not the other class (control group). More specifically, this study employed a pre-test - post-test two-group non-randomised quasi-experimental design (Creswell, 2013), with random assignment of the two classes to the experimental and control groups. The design is represented accordingly:

Treatment Group (receives full treatment): R – O – XOXOXO – O

Control Group (receives no treatment): R – O – O

where: R represents the random assignment of groups

O represents one of the measures (Pre-test, Post-test, Rate My Game)

X represents treatment employed (Gamified tangrams and origami activities)

This approach compared changes in the achievement of both classes over the intervention, to determine whether students who were exposed to the intervention attained greater gains than those who were not (Sousa et al., 2007).

Merging of the data sets occurred in the data integration stage, where joint displays and narratives (Fetters, Curry, & Creswell, 2013) are used for analysis and comparison. Merging took place after the statistical analyses of test data and the thematic analysis of the students and teacher's data. Mixing methods permitted an optimum mix (Teddlie & Tashakkori, 2009; Johnson & Onwuegbuzie, 2004) of both quantitative and qualitative methods, and mixing findings at the level of inference upon completion of the independent analysis of quantitative and qualitative data (Leech & Onwuegbuzie, 2009).

Collecting different but complementary data sets clarifies the research issue by capturing the strengths and non-overlapping weaknesses of both quantitative and qualitative methods (Creswell & Plano Clark, 2011), to draw conclusions and make inferences about the effectiveness of the treatment in the accessible population. Quantitative methods provided a general assessment of students' achievement in geometry and their perceptions of educational games in mathematics, while qualitative methods provided some elaboration on student and teacher perceptions. This "expansive and creative" (Johnson & Onwuegbuzie, 2004, p. 23) approach circumvented the limitations of "purism about the epistemological origins of [a single] approach" (Snape & Spencer, 2003, p. 17).

Sample

The population of interest for this study was Standard 5 (Grade 6) students in Trinidad and Tobago. However, the accessible population comprised the Standard 5 (Grade 6) classes in the St. George East education district in Trinidad. One private primary school was purposively selected from among the primary schools in the education district. The average age of students in the study was 11 yrs., and all had completed the terminal examination. The sample comprised two classes, one experimental group (n = 16), and a control group (n = 17). Although the accessible sample for this pilot study was not entirely representative of the population of interest, the primary purpose of this study was not to generalise to the entire population but to explore the feasibility of its design and methods with an accessible sample, and modify them for the main study. The teacher of the experimental group was purposively selected for interview to gain insight into experiences with the gamification of the tangram and origami puzzles.

Procedure

A workshop for teachers on the use of games in mathematics education was facilitated at the research site in April 2016 and preceded the commencement of the study there. Teachers were oriented to the use of educational games in general and, specifically, how the selected games were to be implemented during the study. Subsequently, the researchers obtained permission from the school's Board of Management to conduct the study at the school, and informed consent from participating teachers and the parents/guardians of participating students. The experimental group's teacher was provided with instructional materials, and oriented to the implementation requirements. Data collection occurred in May 2016 via the administration of pre-tests to both experimental and control groups, by their teachers. The experimental group played the tangram and origami games during five 60-minute periods over five days. After each game was played, students completed the *Rate My Game* questionnaire. The experimental group's teacher collected samples of the students' work and provided the researchers with her observational notes. The researchers visited the site to provide guidance when required. Upon completion of the treatment, the post-test was administered to both experimental and control groups. The experimental group's teacher was interviewed about her perception of the use of the gamified tangram and origami activities, the students' overall levels of engagement in play, challenges they experienced, and their social interaction during play.

The gamification procedure

The Huang and Soman (2013) five-step gamification process for the unit in geometry was adopted. The Standard 5 (Grade 6) students were selected, because they were in a state of transition to secondary school, and reinforcement of geometrical concepts and skills would be beneficial. The gamified classroom brought minimal risk to the students. Having identified clear learning objectives from the primary curriculum aligned with geometry, reinforcing geometrical concepts was determined as the focus of the gamification.

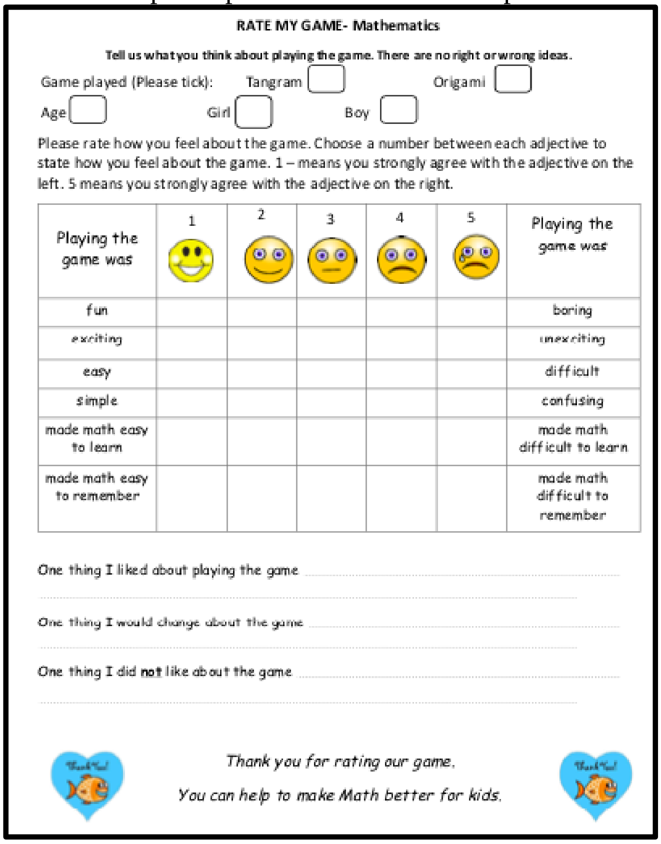
Tangrams and origami puzzles were selected for gamification with the teacher as the game facilitator. The researchers sourced paper and designs for the puzzles and designed challenges at the first three levels of geometric thinking according to van Hiele (1999). In the activities, at the visual level, students explored geometric shapes through visualisation and manipulation. This can help primary school students clarify misconceptions about geometric concepts if their mental perceptions differ from formal definitions of these concepts. For example, they sometimes have difficulty identifying plane shapes like squares, triangles and rectangles when they are rotated. At the analysis level, manipulation of shapes can help students bridge the gap between concrete representations of shapes and abstractions of these concepts. For example, students can classify shapes according to their properties. Finally, at the abstraction level, students can deduce relationships between different properties of a shape, identify related shapes, and explain their reasoning about similarities and differences among shapes and their properties. A scoring system and rules of the games were established for the gamified activities. A rating scale was adapted from Knezek, Christensen, and Tyler-Wood's (2010) to capture students' perspectives on the game. Finally, game mechanics were designed to focus the students on competing with themselves and their classmates. Gaming elements included restriction of time to complete tasks, immediate feedback and rewards from the teacher.

Data Collection and Analysis

Qualitative methods were utilised for research question 1, to collect data regarding student perspectives on educational games via questionnaires; and for research question 3, to collect data regarding the class teacher's perspective on educational games via her observational notes and exit interview. Qualitative methods provided a rich deep understanding of how human experiences, thoughts and feelings are "understood, experienced, or produced" (Mason, 1996, p. 4) in a particular context (Patton, 2002). Quantitative methods were utilised for research question 2, to collect data regarding students' geometric thinking skills via parallel pre-test and post-test. Quantitative methods were used to summarise data and "describe current conditions … [and] investigate relationships" (Gay & Airasian, 2000, p. 11).

Research question 1

A *Rate My Game* questionnaire (see Figure 1) was administered to students at the end of each game played requiring them to write their perspectives on what they liked, did not like, and would change about the game. Open responses were thematically analysed as a first means of data reduction (Miles & Huberman, 2002), and then each theme was binarised to produce an inter-respondent matrix (Onwuegbuzie, 2003) indicating the prevalence of that theme through frequency counts. These frequencies were then converted to percentages reflecting the intensity effect size per theme. Factor analysis led to the emergence of meta-themes regarding what was favourable, unfavourable and needed change. Inferential statistics were utilised as Onwuegbuzie (2003) argued that inferential statistics are valuable in qualitative analyses where words from participants are treated as sample units of data.



RATE MY GAME- Mathematics

Tell us what you think about playing the game. There are no right or wrong ideas.

Game played (Please tick): Tangram ☐ Origami ☐

Age ☐ Girl ☐ Boy ☐

Please rate how you feel about the game. Choose a number between each adjective to state how you feel about the game. 1 – means you strongly agree with the adjective on the left. 5 means you strongly agree with the adjective on the right.

Playing the game was	1	2	3	4	5	Playing the game was
fun						boring
exciting						unexciting
easy						difficult
simple						confusing
made math easy to learn						made math difficult to learn
made math easy to remember						made math difficult to remember

One thing I liked about playing the game ....

One thing I would change about the game ....

One thing I did **not** like about the game ....

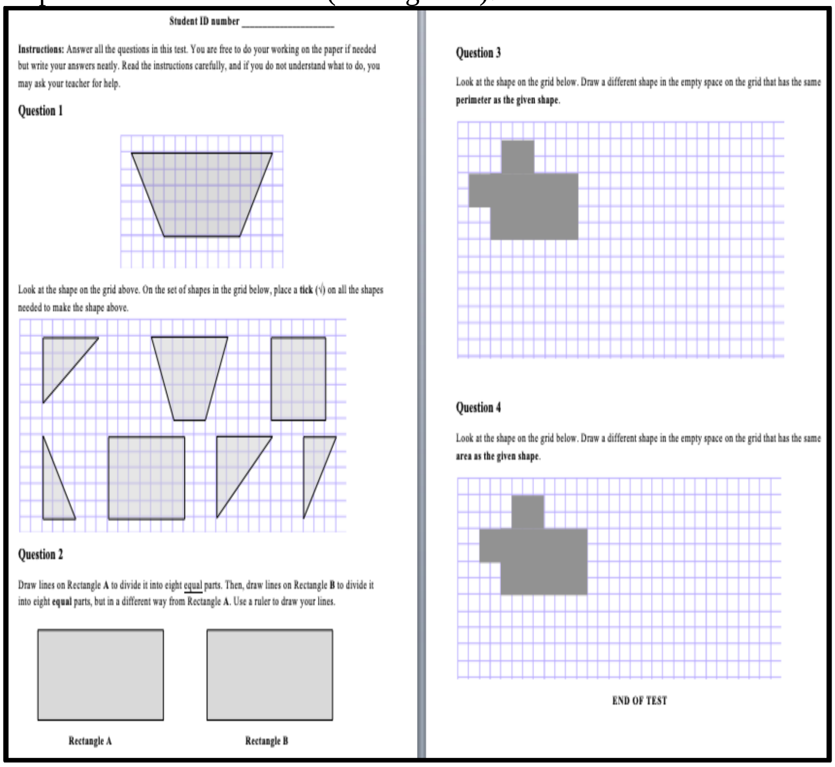
Thank you for rating our game.

You can help to make Math better for kids.

***Figure 1*. Rate My Game student questionnaire.**

Research question 2

Equivalent pre-tests and post-tests were designed to explore students' ability to apply geometric thinking to respond to items that addressed specific concepts and skills in Geometry. Each test each comprised 4 items (see Figure 2). On both pre-test and post-test, Item 1 required recognition of simple shapes that comprise a compound shape. Students identified and selected from a set of simple shapes, those that comprised a given compound shape. Item 2 required dividing a whole into parts. Students used a ruler and pencil to uniquely divide each of two congruent rectangles into 12 equal parts. Item 3 required demonstration and application of principles of Perimeter. Students were provided with a plane shape on a grid, and on the same grid drew a different plane shape with the same perimeter. Item 4 required demonstration and application of principles of Area. Students were provided with a plane shape on a grid, and on the same grid drew a different plane shape with the same area. The tests were not timed, allowing students to work at their own pace. Students' responses were assessed using a rubric designed to capture a range of responses to the four items (see Figure 3).


Student ID number ________________

Instructions: Answer all the questions in this test. You are free to do your working on the paper if needed but write your answers neatly. Read the instructions carefully, and if you do not understand what to do, you may ask your teacher for help.

Question 1

Look at the shape on the grid above. On the set of shapes in the grid below, place a **tick** (√) on all the shapes needed to make the shape above.

Question 2

Draw lines on Rectangle **A** to divide it into eight equal parts. Then, draw lines on Rectangle **B** to divide it into eight **equal** parts, but in a different way from Rectangle **A**. Use a ruler to draw your lines.

Rectangle A **Rectangle B**

Question 3

Look at the shape on the grid below. Draw a different shape in the empty space on the grid that has the same **perimeter as the given shape**.

Question 4

Look at the shape on the grid below. Draw a different shape in the empty space on the grid that has the same **area as the given shape**.

END OF TEST

***Figure 2*. Geometry achievement test administered pre-intervention**

Test Rubric				
Item #	3 points	2 points	1 point	0 point
1	All correct shapes identified	Any 2 correct shapes identified	Any 1 correct shape identified	No correct shapes identified
2	Different configurations No perceptible unequal parts	Different configurations Few visibly unequal parts	Different configurations Some visibly unequal parts	Identical configurations Visibly unequal parts
3		Different shape with same perimeter	Different shape with incorrect perimeter with evidence of minor error in counting	Different shape with incorrect perimeter **or** Same shape with same perimeter
4		Different shape with same area	Different shape with incorrect area with evidence of minor error in counting	Different shape with incorrect area **OR** Same shape with same area

***Figure 3*. Rubric for scoring pre-test and post-test.**

Pre-test and post-test scores were tabulated for each student, and SPSS ver. 21 software was utilised to compute group means and standard deviations for pre-test and post-test scores. Paired-samples t-tests (2-tailed, .05 significance level) were conducted to identify significant differences between each group's pre-test and post-test scores. An independent-samples t-tests (2-tailed, .05 significance level) was computed to determine whether there was a significant difference in groups' mean pre-test and post-test scores.

Research question 3

The teacher's perspective was elicited through her observational notes and an unstructured face-to face-interview. Her notes were analysed using qualitative content analysis to determine levels of student engagement and enjoyment during each game, and the ease of implementation of educational mathematics games. The interview captured her perspectives on her experiences to reveal meanings that she attached to these experiences (Ponterotto, 2005). The interview was videotaped with her consent. Members of the research team independently analysed the interview using qualitative comparative analysis to identify emerging categories of meaning and their interrelationships (Glaser & Strauss, 1967), and to interpret their meaning (Schreier, 2012). Individual codes and categories were compared for convergence or divergence of emergent themes and their interpretation. Agreed-upon categories were reported and described for the reader to follow (Schreier, 2012).

Ethical Considerations

Permission was obtained from the school board, the principal and parents to conduct the study. To protect the identity of participants, each student was given a code which he/she recorded on the pre-test and post-test, and the school remained un-named. Further, only group statistics were reported. Parents had the option to refuse participation of their child/ward in the study with no negative repercussions. All students were exposed to the study, but data were only collected and used once permission was obtained. Data were stored in a fire-proof filing cabinet, using password protected media, accessible only to the researchers.

Findings

Findings are presented below, with respect to the three research questions.

Research Question 1

Data collected from the *Rate my Game* questionnaires yielded qualitative responses for three questions: liked, not liked, and change. Representational themes from participant words in each category led to the development of an inter-respondent matrix resulting in three meta-themes coded as Favourable, Unfavourable and Change (see Table 1). The responses for the two gamified activities - origami and tangrams - were combined.

Table 1. ***Representational themes from students' rating scales and researchers' assertions***

ORIGAMI		**TANGRAM**		**ASSERTIONS**
Text/Axial Coding	**Representational Themes**	**Text/Axial Coding**	**Representational Themes**	**Interpretive Themes**
*Students liked the folding activity.	*(x6) Activity Based	*Working together in groups.	*(x8) Cooperative learning	FAVORABLE We loved these games primarily, because they were fun and activity-based and they helped us to learn from each other. Though largely challenging, the games helped us become more creative and innovative math students.
*Students liked seeing the finished product.	*(x4) Realistic achievable goals	*More FUN than actual work *Creating Art using familiar shapes	*(x5) Fun	
*Students liked everything about the game.	*(x4) Fun	*It was mind challenging	*(x5) Creativity	
*Making all different paper creatures.			*(x3) Challenging	
*Brings something new.	*(x4) Creativity			
	*(x2) Innovative			
*Many students loved the game as is and would change nothing about it.	*(x12) Nothing	*Many students loved the game as is and would change nothing about it.	*(x6) Nothing	UNFAVORABLE Students loved the origami (70%) more than the tangram (35%). Overall, more students loved the games and did not find anything they did not like. However, a few students (12%) felt that the games were "challenging" or too complex (35%).
*The phrasing of instruction for clarity and understanding.	*(x5) Change the instruction.	*Challenging since only few shapes were utilised.	*(x2) Challenging	
*We did not like some of the activities e.g. making the rocket.		*Some of the activities were a little too hard.	*(x6) Complexity	

ORIGAMI		TANGRAM		ASSERTIONS
Text/Axial Coding	**Representational Themes**	**Text/Axial Coding**	**Representational Themes**	**Interpretive Themes**
	*(x2) Specific Task	*Difficult to put shapes together.	*(x3) Difficult	
*Many students loved the game as is and would change nothing about it. *Instructions should be simpler. *Nothing was FUN. *Reduce the folding.	*(x12) Nothing *(x5) Too complex *(x4) Not Fun *(x2) Too complex	* Many students loved the game as is and would change nothing about it. *The level of difficulty too high. *Want more shapes from tangram *Lessen the number of shapes and the instructions should be easier to understand.	*(x6) Nothing *(x3) Too complex *(x4) Too complex *(x4) Complexity	CHANGE Many of the students loved the game as is and would change nothing. However, a significant number suggested a change to the level of complexity. A few students (23%) felt like the games lacked the crucial 'fun' element that they considered key to any successful game.

The *Favourable* theme asserted that students loved these games as they were primarily fun and activity-based and they helped them to learn from each other. Even though they thought the games were a bit challenging, they felt that the games helped them to become more creative and innovative math students. This meta-theme resulted from statements from students that they "liked the folding activity", "liked everything about the game", felt it was "more fun than actual work" and "was mind challenging"; they thought it "brings something new" and they "liked working in groups". The idea of the game being challenging was noted for tangrams but not for origami.

The *Unfavourable* theme asserted that most of the students found 'nothing' unfavourable about the games, but tangrams were less favourable than origami. Students indicated the games were challenging (12%), and either too complex (35%) or too difficult (6%). Some students found that the tangrams were a "little too hard" with 2 students writing that it was "difficult to put the [tangram] shapes together". Significant, too, was the view that the origami instructions needed to be made clearer, and two students expressed that they did not like the activity, such as the rocket. Generally, complexity seemed to be unfavourable.

The *Change* theme asserted that most students loved the games and would change "nothing" about it. However, in response to the complexity theme, students made some suggestions for change to the game. They "wanted more [tangrams] shapes", and "to lessen the number of shapes" and felt that "the instructions should be easier to understand". Some students (24%) felt that the games lacked the crucial fun element that they considered key to any successful game. In a few cases, recommendations were made to change the game instructions.

Research Question 2

Students' scores were tabulated, and means and standard deviations were computed. Independent samples t-tests were computed to compare the pre-test and post-test achievement of the experimental and control groups. A significant difference was observed between the groups' pre-test scores, t = -2.482, p =.019; the experimental group (M=6.69, SD=1.493) scored significantly lower than the control group (M=8.00, SD=1.541). However, no significant difference was observed between the post-test scores of the experimental group (M=8.00, SD=1.461) and the control group (M=8.00, SD=1.581). Inspection of groups' pre-test and post-test scores indicated some fluctuation from pre-test to post-test. In the control group, students' scores were relatively stable; however, in the experimental group, all but one student achieved a higher post-test score than pre-test score (see Figure 4).

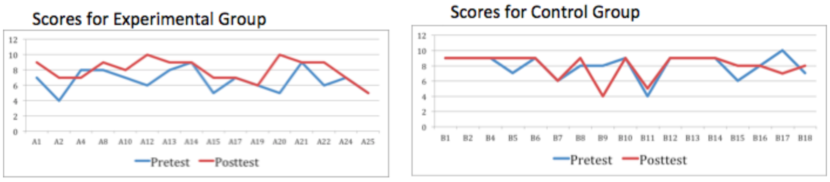


***Figure 4.* Pre-test and post-test scores for the control group and experimental group.**

Paired samples t-tests were computed to compare the groups' pre-test and post-test scores. There was a significant difference within the experimental groups' scores, t = -3.085, p <.01, from pre-test (M=6.69, SD=1.493) to post-test (M=8.00, SD=1.461), with a smaller standard deviation. However, there was no significant difference observed between the control group's pre-test and post-test scores.

Research Question 3

Qualitative comparative analysis of the responses from the teacher's observational notes and the interview yielded seven themes: *fun*:- students had fun playing games with each other; *easy to use*:- students found the puzzles and the material easy to manipulate; *co-operation*:- students demonstrated their willingness to work together to do what was required to ensure that all team members completed their part to win the games; *respectful competition*:- student-teams actively competed against each other maintaining respectful interactions, and willingly assisted other teams that struggled to complete the games; *ownership*:- students took pride in their products, decorating and naming their designs; *reinforcing concepts*:- students' participation in the games allowed them to demonstrate their ability to apply their existing knowledge of geometric concepts and skills to create tangrams and origami figures; and *engagement*:- students demonstrated high levels of enthusiasm and determination to complete games, even when they encountered challenges. These themes and direct quotes to support them are summarised in Table 2.

Table 2. *Thematic analysis of teacher's perspectives*

Theme	Significant statements reflecting the theme
Fun	"[students] did not feel like [they were] doing math" "[students] had the most fun with origami"
Easy to use	"the children were able to make the [tangram] shapes much faster than myself as an adult"

Theme	Significant statements reflecting the theme
	"Origami was child-friendly"
Co-operation	"[students] enjoyed group work and co-operated with each other" "students who finished would help others" " [there was] collaboration within teams and between teams"
Respectful competition	"[students] got really competitive for tangrams" "[students] were respectful to each other during the games even though they were competing against each other"
Ownership	"they enjoyed naming their creations" "[students] liked to see products and name them"
Reinforcing concepts	"they were able to identify line of symmetry in origami without being told" "students grasped the tangram concepts easily" "they could make the shapes by figuring how they fit together using their properties"
Engagement	"[students] were so engaged in the games"

Overall, the teacher reported high levels of student engagement, collaboration within teams and respectful competition among teams during play, as well as evidence of reinforcement of prior learning through gameplay.

Discussion

The discussion is organised around each research question.

Research Question 1

Favourable assertions about the games were evident in students' ratings of both tangram and origami puzzles as fun, activity-based and challenging. Origami appeared to be more favourable than the tangrams, where complexity and levels of difficulty were noted. These findings with primary school students support those of Boakes' (2009) study of middle school US students with origami activities. However, Cakmak et al. (2014) noted that students experienced difficulties that had to be overcome, which corroborate the assertions of some students in this study who felt that the games were 'not fun', 'too complex' or 'challenging'. The literature suggests that overcoming challenges is a major area of interest in playing games

(Kapp, 2012), more so than for external rewards like points and winning. It is notable that students did not comment on winning prizes or gaining points as motivators for the game, but instead indicated teamwork, challenge and activity as favourable. This important finding suggests that the gamification in this study was effective, and game elements of challenge, continual feedback and a high level of interactivity were critical in engaging students, which supports the findings of Kapp (2012).

Further, students were able to develop their geometry vocabulary; their skills in shape identification, classification, and orientation; their understanding of basic geometric concepts and relationships; and their spatial sense in the world around them, which corroborated the findings of researchers like Bohning and Althouse (1997), Lin et al. (2011), and Yang and Chen (2010). They were able to clearly identify where tasks were not clearly instructed, were overly complex or required more shapes, revealing some development of their analytical, creative, and logical thinking, outcomes also reported by Russell and Bologna (1982), Siew et al. (2013), and Yang and Chen (2010).

Research Question 2

The results indicated that although the experimental and control groups differed significantly in their pre-test scores, their post-test scores were not significantly different. Further, there was an observed significant difference in the scores of the experimental group. Pre-test scores suggested that the experimental group's performance was lower than the control group at the start of the intervention, but performance equalised after exposure to the intervention. This finding supports those of other researchers, including González et al. (2014), Huang and Soman (2013), Papp (2017), Preist and Jones (2015), and Yildirim (2017), who indicated that gamification contributes to enhancing student understanding and, hence, their performance. It is likely that the gains in the performance of the experimental group were associated with the change in the learning environment (Cheong et al., 2014) through the use of gamified tangrams and origami activities. The game-oriented learning environment facilitated reinforcement of students' understanding of basic geometric concepts and relationships, such as shape identification and orientation, symmetry, spatial awareness (for example, Boakes, 2009; Bohning & Althouse, 1997; Lin et al., 2011; Yang & Chen, 2010), task performance and decision making (for example, Gal & Lew, 2008), and enhanced performance of students in the lower achieving group (for example, Papp, 2017).

Research Question 3

Themes emerging from this research such as Competition and Fun, support Bragg (2007) who suggested that games can promote competition, and educational games can help learners to develop mathematical skills while increasing student interest and motivation. The findings also corroborate Cheong et al. (2014) who found that students feel more interested and motivated to learn in a gamified environment. Fun was a definite element in the gamified environment in this study, as well as those conducted by Papp (2017) and Sanchez Mena et al. (2017). Another emerging theme was co-operation. The teacher referred to students co-operating and assisting each other through social interaction, as in Sanchez Mena and Marti Parreno's (2017) study, in which their teacher-participants reported that a gamified environment promoted social interaction among students, which aligns with the desired 21st century skills of communication and sharing (Landers & Callan, 2011).

Overall Integrated Findings

From analysing the data in the three research questions, three integrated themes were found: games are fun; gamification leads to student engagement; the gamified activities using origami and tangrams led to the reinforcement of geometry skills and concepts. Data obtained from both the teacher and students corroborated the finding that students enjoyed playing the games. Students reported that they liked the origami games more than the tangram activities. The themes of cooperation and teamwork were also confirmed by both data sets. Themes related to complexity were highlighted by the students but not the teacher; meanwhile, the teacher expanded previous themes with the idea of ownership. The role of ownership as it applies to student interest and motivation needs greater attention, especially with respect to student creation of artefacts. In this study, it appeared that this was a motivating factor for students.

The notion that games can be used as a learning tool to reinforce geometrical concepts was evident in this study. As in the findings reported by Brady (2008) and Boakes (2009), the teacher in this study found that tangrams and origami games supported and reinforced students' understanding of geometrical concepts and relationships. This was demonstrated by their ability to identify and use lines of symmetry to create origami models, and the properties of shapes to solve tangram puzzles. The teacher reported high student engagement during the intervention. Student engagement manifested in students' motivation, interest and attention to complete challenges during gameplay (Sanchez Mena & Martí Parreno, 2017). The themes from the student and teacher data are summarised in Table 3.

Table 3. ***Joint display of integrated themes from student and teacher data***

Integrated Themes	Students	Teacher
Games are Fun	"More FUN than actual work"	"Did not feel like [they were] doing math"
Gamification leads to student engagement,	"Students liked everything about the game"	"[students] were so engaged in the games"
The gamified activities using origami and tangrams led to the reinforcement of geometry skills and concepts	Students liked "the folding [Origami] activity". "…want more shapes from tangram"	"They were able to identify line of symmetry in origami without being told" "Students grasped the tangram concepts easily" "They could make the shapes by figuring how they fit together using their properties"

When we combine these findings with the results on tests where the experimental group's pre-test scores (M=6.69, SD=1.493) increased to higher post-test scores (M=8.00, SD=1.461), we may conclude that gains in students' achievement could be associated with the gamification intervention. These gains include reinforcement of their geometric concepts and skills, positive orientation towards gamification in mathematics, and perceiving games as meaningful and engaging learning tools that develop their creativity and innovativeness, if the games were fun, challenging and not overly complex. The quantisation of student responses allowed themes related to student engagement to emerge, thus, expanding understanding of this phenomenon.

Conclusion

In summary, students' perspectives on the use of gamified tangram and origami activities in geometry were favourable; gains in achievement were realised and the teacher supported the gamified activities as learning tools for teaching geometry concepts and interrelations among them. Hence, it is concluded that there is potential in gamifying mathematics to encourage active and collaborative learning and student engagement in learning mathematics, and develop geometric concepts and skills in the Trinidad and Tobago primary classroom.

Recommendations

These findings provided researchers with invaluable feedback for strengthening the main study in one education district in Trinidad and Tobago. A major recommendation in this regard is to attend more carefully to the first level in the Huang and Soman's (2013) model when designing the games to be a meaningful learning tool, particularly with respect to closer collaboration with the class teacher who brings intimate knowledge about students and the learning environment. Consideration to the target group of students and their prerequisite knowledge and skills in the given learning context are critical to designing tasks that cover the curriculum content, and are sufficiently challenging to keep students interested in playing without frustrating them.

Secondly, these findings are instructive to refining the design of game elements for enhanced student engagement, improved academic achievement and positive attitudes towards mathematics (Hoffmann et al., 2009). This could be particularly helpful in catering to the needs of diverse Caribbean student populations in terms of gender, ability, interest and cultural contexts, as well as can reveal a greater understanding of how gamification aids learning in primary classrooms.

Finally, we wish to underscore the critical importance of the cooperative role of the teacher(s) and the principal of the school in the gamification process. Educators from administrative to classroom levels should be exposed to the possibility of gamified classrooms for more engaged learning. More collaboration is required between teacher-education researchers at the university, and classroom teachers, to facilitate further research on gamification in mathematics.

Implications

The study is significant to the researchers as it was a pilot study for a larger project in 10 schools. For the researchers, data from this pilot inform the design and implementation of the larger study to follow, by examining the selection of learning tools, the focus on specific concepts and skills for the selected level, the choice of sampling group, the gamification elements and challenges faced by teachers in gamifying mathematics classrooms.

The staff and administration of the school used in the study were exposed to a different approach to teaching geometry. The teacher for the experimental group could benefit from her exposure to experimenting with a new strategy for reinforcing geometric concepts and skills. The students involved in the experimental group were exposed to elements of gameplay in a structured setting to engage them in active learning. Additionally, student and teacher perspectives of gamification are important to gain insight into the use of games and their application to other content strands in Mathematics.

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