Caribbean Educational Research Journal
Volume 6, Issue 2, October 2021, 69 - 100

THREE NON-DIGITAL MATHEMATICS GAMES TO ENGAGE STUDENTS IN LEARNING MATHEMATICS

Sharon Jaggernauth*
The University of the West Indies, St. Augustine

Faleesha Lochan
Ministry of Education, Trinidad and Tobago

Abstract: *This paper introduces three non-digital team games that were designed and created by the authors to align with the Measurement strand in the Trinidad and Tobago secondary schools mathematics curriculum for Grades 8 and 9. The games were integrated into the teaching of the circumference of circles in a Grade 9 mathematics classroom at a government secondary school in Trinidad and Tobago where students struggled with mathematical problem solving and demonstrated negative classroom behaviour and attitudes towards learning mathematics. The paper describes how the games were aligned with the curriculum to support learning and how they were implemented. The outcomes of each are presented in terms of students' perceptions of their effects on the learning environment and the teacher's perception of their effects on student engagement in learning. The games engaged students in inductive inquiry into mathematical relationships related to circumference of circles, including deriving Pi through measurement, and solving simple authentic mathematics problems involving the perimeter of compound shapes comprising semicircle and quarter circle components. Students reportedly enjoyed learning mathematics in the mentally stimulating learning environment with their friends that allowed them to work together to support their individual and collective learning. The teacher reported that students actively participated and engaged in game-tasks and supported each other through challenges. However, poorly developed reading comprehension skills interrupted students' progress in one heavily text-based problem-solving game. But they completed the game with some assistance from the teacher with problem analysis. This paper offers tangible evidence, at least at the study site, that non-digital learning games that are aligned with curriculum objectives and students' interests, knowledge and abilities can support student learning outcomes in mathematics.*

Keywords: *non-digital learning games, mathematics, secondary schools, Trinidad and Tobago*

* Corresponding Author (sharon.jaggernauth@sta.uwi.edu)

ISSN 1727-5512

INTRODUCTION

Mathematics teachers around the world often complain that students are not meaningfully engaged in learning mathematics and, consequently, achievement rates in mathematics are lower than desired (Martin & Marsh, 2006). How mathematics is taught can affect students' perceptions of and attitude towards mathematics and their mathematics achievement (Karigi & Tumuti, 2015). Laird and Grootenboer (2018) opined that a growing number of students become disengaged from learning mathematics because they perceive it as boring and difficult to learn. Sullivan and McDonough (2007) encouraged teachers to experiment with teaching and learning activities that would foster student engagement in learning, as well as their mathematics confidence. The National Council of Teachers of Mathematics (NCTM) continues to support mathematics educators with teaching and learning. The NCTM (2014), out of concern about issues of equity and access in mathematics education, formally articulated their position on these issues: the teaching of mathematics requires focus on students' backgrounds, experiences, cultural perspectives, traditions, and knowledge, and attention to creating, supporting and sustaining learning environments in which students receive high quality instruction and differential learning supports to reduce the occurrence of differential student outcomes. These are also concerns for Trinidad and Tobago as a Caribbean nation that is culturally, racially and ethnically diverse, and whose students must connect with school mathematics because it is a gateway to higher education in which mathematics has become integrated (e.g., psychology and sociology) and employment in the global workforce (Namukasa, 2004). Therefore, teachers must employ pedagogical strategies that provide a context and purpose for learning mathematics, and incorporate students' interests and personal experiences with mathematical ideas outside the classroom. One such pedagogical approach is the integration of learning games into mathematics instruction.

Research suggests that integrating games into mathematics instruction can improve students' engagement in learning, increase their overall satisfaction with learning mathematics, and improve their mathematics performance (Bragg, 2007; Massey et al., 2005). Research at the primary/elementary level in Trinidad and Tobago has also revealed similar findings (Kalloo et al., 2019; Jaggernauth, et al., in press), but this has not been verified at the secondary level. This paper reports on three non-digital learning games (NDLG) that were integrated into a Grade 9 classroom at a government secondary school in Trinidad and Tobago. Students in this class demonstrated low engagement in learning activities during mathematics lessons, and experienced difficulty in mathematical problem solving. This paper presents a theoretical overview regarding learning games as a pedagogical approach, followed by the research purpose and methods, and the findings and discussion against the background of the research literature on learning games.

BACKGROUND

Mathematics teachers often complain that students do not value the mathematics they learn at school and its applications in daily life. Various factors contribute to these observations, a major one being related to teachers and the teaching of mathematics. Dewey (1938) argued that learning is meaningful when it is grounded in learners' experiences rather than focused on skills acquisition along subject lines. Schoenfeld (1998) supported this argument, adding that it is more problematic when teachers rely on routine textbook problems. When teachers present mathematics as a formal collection of facts and theorems to be learned, without creating opportunities for students to explore and investigate mathematical concepts and relationships through social inquiry, students begin to perceive mathematics as being boring, abstract, difficult to learn and irrelevant to daily life (NCTM, 2014). Consequently, their engagement in learning mathematics is low, a problem that Hamari et al. (2016) described as globally pervasive.

Learning games differ from traditional games because although they have rules that guide them, they focus on educational outcomes, and they involve the teacher in organizing and managing the learning environment and require student participation. Vankúš (2013) classified this approach as a teaching method. Researchers suggest that learning games engage students in social learning and develop their cooperative and creative thinking (Dofková & Uhlířová, 2016), motivating them to learn through the enjoyment and competitiveness of gameplay (Vankúš, 2013). These important benefits of learning games make them ideal for teaching mathematics, particularly for students who struggle with learning and doing mathematics and who hold negative attitudes towards the subject. Researchers such as Shute et al. (2011), advocate research on learning games in classrooms.

This paper reports on the outcomes of selected games from a game-based intervention implemented by a teacher at one government secondary school in Trinidad. The teacher reportedly seldom experimented with non-traditional pedagogical approaches because her students were easily distracted; some were even disruptive during instruction, and she often experienced difficulty keeping students on task during instruction. During her in-service professional teacher training at The University of the West Indies, she engaged her university lecturer in collaborating on a games-based intervention to improve teaching and learning of mathematics in her classroom. This collaborative approach among educators in different fields, such as teaching and teacher education, was recommended by the NCTM (2014) for ensuring equity and access in mathematics education to support student outcomes. The authors posited that the use of learning NDLG, a novel pedagogical approach at the study site, would positively affect students' engagement in learning mathematics and their problem-solving approaches, especially when the content of these games drew upon students' tacit knowledge and past experiences. The games were designed to engage students in cooperative investigations that allowed them to formulate, discuss and critically evaluate conjectures, to create contexts for remembering important relationships and apply them to solving problems. The study focused on the circumference of circles in the Measurement strand of the secondary school curriculum, which required students to understand and use relationships among diameter, circumference and Pi in problem solving.

This paper presents the findings regarding three non-digital games that Grade 9 students played over 10 lessons in a unit on circumference of circles, in response to the following research questions:

1. How did integrating learning NDLG into instruction influence students' perception of the NDLG learning environment?
2. How did integrating learning NDLG into instruction influence perceived student engagement in learning mathematics?

THEORETICAL OVERVIEW

Students' perceptions of mathematics

Negative attitudes towards mathematics and global acceptance of poor mathematics achievement pervade many school systems (Bragg, 2007). Yet, children subconsciously perceive and use mathematics in their everyday lives, for example, in the school cafeteria and in simple activities in the playground. Lave (1988) noted that students think differently about *everyday mathematics* (the mathematics they use in their daily lives) and *school mathematics* (the mathematics they learn formally at school). This false dichotomy supports the notion that mathematics is *something* learned at school rather than the building blocks for everything in our daily lives. Further, when mathematics instruction emphasizes achieving a single *right* answer rather than focuses on developing students' mathematical thinking, students begin to develop negative perceptions about mathematics and actually become less interested and engaged in learning mathematics (Sun & van Es, 2015). Conversely, when students enjoy learning and doing mathematics and can connect *school* mathematics to *everyday* mathematics, they develop positive attitudes towards mathematics, are more interested and motivated to learn mathematics, and improve their mathematics achievement (Mata et al., 2012).

Student engagement in learning

Teaching and learning do not occur in a vacuum, but in classrooms where the simultaneous interaction of the physical, social, psychological and pedagogical domains create and shape the learning environment. Researchers such as Backlund and Hendricks (2013) and Bragg (2007) reported that when learning games engage students in inquiry in mathematics, student motivation to learn mathematics is heightened. Bragg cited a number of sources that support the motivational element of competition, challenge and fun-involved games that facilitate student learning. McGonigal (2011) added that the increase in the level of difficulty and challenges associated with learning games creates a positive form of stress called eustress that motivates players towards success. However, it is difficult to assess an individual's level of motivation because, as Gettinger and Walter (2012) noted, motivation refers to an *intention* to act. Engagement in learning is an easier related construct to define and identify because it refers to an individual's *actual* participation in an act. In other words, engagement is the manifestation of an intention to act. Thus, it is plausible to conclude that students who are motivated to learn will actively engage in learning, and students who are actively engaged in learning are motivated to learn. Research has connected low engagement in learning mathematics and students' limited understanding of the utility of mathematics in daily life with negative consequences for their future (Sullivan et al., 2006). Therefore it is important to attend to student engagement in learning.

Vygotsky (1978) and Lave and Wenger (1991) considered learning to be the outcome of social interactions among individuals who share experiences in supportive learning environments that embrace diversity and contextualize learning. According to Bruner (1961), student learning is most meaningful when it involves activities that are contextually relevant, provide an achievable goal, actively engage students, and stimulate interest in learning. We operationalize the definition of student engagement in learning as that proposed by Radloff and Coates (2010): "students' involvement with activities and conditions likely to generate high-quality learning" (p. 3), which include opportunities for "active and collaborative learning, participation in challenging academic activities, formative communication with [teachers], involvement in enriching educational experiences, [and] feeling legitimated and supported" (p.122). This definition recognizes that student engagement in learning encompasses both academic and non-academic aspects of learning.

Learning games

Hamari et al. (2016) pointed out that the use of games in the classroom surpasses their traditional use as entertainment for students while teachers work. Games can combine play and work for the purpose of facilitating learning. Klopfer et al. (2009) defined learning games as structured play that is driven by intrinsic motivation and active cognitive and physical engagement, which align with the three domains of educational activities (affective, cognitive, and psychomotor) espoused by Bloom et al. (1956). Hromek and Roffey (2009) argued that learning games are experienced-based tools that teachers can use to create a safe and enjoyable social environment that attends to students' social and emotional learning needs – feelings of wellbeing, coping abilities, psychosocial functioning, managing emotions when frustrated, delaying gratification, connectedness, and capacity to learn, while decreasing undesirable behaviour. Learning games have elements of challenge and specific cognitive outcomes, and provide players with opportunities to think and make decisions (Oldfield, 1991). They can be simple adaptations of everyday games that students play (Naik, 2014), and can incorporate everyday materials with which students are familiar.

The use of learning games in mathematics finds support from Harris et al. (2001) who surmised that teachers could improve students' chances of learning mathematics if they introduced mathematics concepts and procedures "through carefully organized collaborative investigations of mathematically rich problems" (p. 310). They also noted that the NCTM recommended that teachers create engaging learning activities that present students with interesting problems, offer them sufficient challenge and appropriate support, engage them in discovery learning and collaborative problem solving to help with learning concepts and problem- solving approaches. Mathematics curricula are replete with opportunities for teachers to create authentic learning contexts that are embedded in students' knowledge, experiences, interests and expertise, that make learning mathematics meaningful to their self-development. Tosto et al. (2016) suggested that learning games can introduce the fun and enjoyment into learning mathematics, and that the increased student interaction relaxes the brain and stimulates positive emotions that improve problem-solving capacity.

Abdul Jabbar and Felicia (2015) surmised that the importance of games to learning is their ability to provide students with enjoyable and motivating contexts to sustain engagement in learning. According to Aldridge and Badham (as cited in Wiersum, 2012), mathematics learning games are successful if they are short and have fewer players than four to allow quick turn-taking, their rules are clear and easy to follow, and they are accessible by students of all abilities so that they feel that they can win the game. These characteristics contribute to developing a learning environment that encourages full participation that is necessary for conceptual development (Paniagua, 2015), and for assessment in a non-threatening environment (Gyöngyösi, 2012). Otherwise, Skotinos (2017) proposed that learning could be jeopardized if the game design and implementation are not tailored to the group of learners and their socialization needs.

Non-digital learning games

The literature on learning games within the last decade focuses heavily on digital games, which is not surprising in the technology-driven 21st century. However, Prensky's (2001) definition of digital games as activities that have the key elements of rules, goals, outcomes, interaction, feedback, challenge, and competition, can be applied to non-digital games as well. Skotinos (2017), suggested that NDLG could also positively affect cognitive, motivational, emotional and social aspects of human behaviour. Vankúš (2013) added other benefits to students, including developing their memory, imagination, creativity, attention, thinking, speech, sensory-motor skills, social skills and emotions; deepening their self-awareness, self-confidence and independence; and preparing them for different social situations (including the working world) through interpersonal communication.

Ayers et al. (2005), Hromeck and Roffe (2009), Mustafa et al. (2011), and Whitton (2012) suggested that NDLG also provide other important aspects of learning. For example, they provide students with opportunities for focused face-to-face social interaction in the classroom that require them to self-regulate and rely on their social skills to experience success in increasingly complex cooperative endeavours. These are characteristics of NDLG that align with the nature of socialization in Caribbean societies which, as Boiselle (2014) pointed out, still occurs primarily through physical human interaction and oral traditions. This animated and physical type of social interaction among Caribbean people is evident in classrooms across the region, and certainly among children globally. Additionally, NDLG remove the dependence on information and communication technologies (ICT) tools, which in many schools in Trinidad and Tobago are scarce, according to Wood-Jackson et al. (2008). Additionally, in many schools across Trinidad and Tobago the ICT infrastructure is insufficient to support the widespread use of personal devices during instruction. It cannot support the simultaneous use of the Internet by multiple devices and/or electrical capacity to support device charging. Therefore, teachers must be resilient and creative when selecting games to support learning. To enhance the appeal and accessibility of the learning, mathematics teachers can design and create NDLG that align with curriculum outcomes and students' learning needs, which can reduce the cost and capital investment in learning resources, an important point highlighted by Naik (2014).

Learning games and student learning

Attard (2012) suggested that physical activity and games can actively engage students in learning mathematics and deepen their mathematical understanding, especially when learning activities highlight the utility and relevance of mathematics to their lives and allow them time to reflect on their learning. Various researchers have touted the benefits of learning games to student learning. For example, Vankúš (2013) suggested that students learn mathematics successfully when games are aligned with their interests and readiness for learning; target and are focused on specific curriculum content; have rules, and sanctions for breaking rules are clear and known ahead of gameplay; are well organized and equipment is available and ready for gameplay; are fair and offer success to all players, given differences in ability and skills among them. Kapp (2012), Rossiter (2007) and Rutherford (2015) advocated learning games that offer discussion, practice and mental engagement to develop students' problem-solving and critical- thinking skills in mathematics. Such games help students resolve the cognitive disequilibrium they might experience upon exposure to new ideas and experiences, by helping them to assimilate or accommodate new ideas. Rathva (2012) opined that the consistent use of learning games could aid with long-term recall and strengthening confidence in the subject. For these reasons, games that involve some aspect of problem solving or inquiry can be quite beneficial for learning. However, Harris et al. (2001) cautioned that problem-solving or inquiry-based approaches are only effective when the teacher makes explicit the prerequisite mathematical concepts for the tasks.

Teachers can design games to provide students with problem-based and inquiry-based learning experiences with exposure to open-ended problems that are appropriately challenging for their level (Hmelo-Silver, 2004). Harris et al. (2001) offered an approach to problem solving that allows students to play mathematics learning games in small groups or teams, which is followed by the teacher engaging students in a whole-class discussion of their ideas. The teacher can probe students' thinking, allowing them to share, examine, justify and reflect on their thinking processes, and in that way develop their ability to appreciate multiple ways of solving mathematics problems. The teacher can also probe students to focus their attention on the relevant mathematics content, and to assess their understanding about the mathematics content they should have learned. In this way, games are integrated into the curriculum to actively engage students in learning through play, with the teacher intervening only when necessary. These are important outcomes for students because of the pervasiveness of negative attitudes towards mathematics and global acceptance of poor achievement success in mathematics (Bragg, 2007).

The highly interactive and social context of learning games develops students' conceptual understanding of mathematical ideas (Bragg, 2012) and meaningful application of mathematical knowledge and skills, which can motivate them to learn, strengthen their self-concept and develop positive attitudes towards mathematics (Davies, 1995). These social interactions scaffold students' learning by providing feedback and assistance when needed (Vygotsky, 1976), which can contribute to their decision making during play. Unfortunately, the integration of learning games into instruction is not a straightforward process. Backlund and Hendricks (2013) highlighted the following challenges that teachers can face when they decide to integrate learning games into teaching and learning: the relevance of games to the curriculum and teachers' ability to integrate them into short lessons; stakeholder scepticism (e.g., parents, teachers and students) about games as a learning tool; teachers' knowledge and ability to integrate games into the classroom; difficulties involved in assessing the true effects of learning games on student learning. With these concerns in mind, we designed and created games that were culturally and contextually relevant to the students at the study site, and that were aligned with their interests and abilities.

In summary, learning games have been proposed by numerous researchers as a tool for developing students' personalities, dispositions and attitudes towards mathematics, their thinking and reasoning about mathematical concepts and problems, their mathematical problem solving, and their ability to work cooperatively to solve problems in a highly interactive and social environment that motivates them to actively engage in learning mathematics.

STUDY CONTEXT

Students who enrolled in Grade 7 at the school in the present study typically earned between 0 and 30% in the Secondary Entrance Assessment (SEA), and many of them struggled to achieve academic success in mathematics during their school life. In fact, from 2015 to 2018, on average, one student per year passed the Caribbean Secondary Education Certificate (CSEC) Mathematics examination. Although students typically demonstrated disengaged behaviour and disinterest in learning mathematics and other traditional academic subjects, many of them were adept at sports and music, and demonstrated keen interest in non-traditional academic subjects, including beauty culture, home economics, garment design, and music. Though their teachers recognized where students' interests lay, they did not use these non-traditional areas to create activity-based learning opportunities to engage their imagination and talents. Teachers continued to rely on teacher-centred traditional instruction, and students continued to fall short of desired learning outcomes. The absence of empirical evidence about the success of non-traditional instructional strategies, such as NDLG, in engaging students in learning mathematics at the school under study provided the impetus to undertake this research.

RESEARCH PURPOSE AND DESIGN

This paper reports on part of an action research study that was designed to explore the integration of teacher-created NDLG into mathematics instruction to confront the classroom problems of students' poor engagement in learning mathematics and poor mathematics achievement. Lincoln and Guba (1985) offered naturalistic inquiry as an approach to studying individuals' lived experiences in their natural environment. In the present study, we designed NDLG for teaching Grade 9 students about the applications of the circumference of circles during a 10-lesson unit, at one government school in Trinidad and Tobago. The design of the NDLG was guided by the research literature about learning games, relevant sections of the Trinidad and Tobago mathematics curriculum for Grades 8 and 9, and students' interests and experiences outside of the classroom. We introduced the NDLG at appropriate times during each mathematics lesson, and observed how students interacted with each other in the environment, to determine how these interactions influenced student engagement in learning mathematics, and the quality of their responses to solving problems that people encounter daily.

Participants

Given the research objective of achieving a deeper understanding of how students responded to the NDLG, one Grade 9 class comprising 20 students (12 boys and 8 girls) aged 14 to 18 years was selected. This group of students was purposively selected because, based on our experience, this class comprised students who were typical of those in the school and in the particular grade level (Patton, 2002). These students were considered to be an information-rich resource (Creswell & Plano-Clark, 2011), and were willing to participate in the study and provide in-depth feedback to the researchers (Patton, 2002).

Many students in the sample attended class irregularly and their punctuality was poor. It was not uncommon for some of them to sleep through class, and those who were not asleep often did not participate in learning activities. Many of them did not attempt or complete seatwork or homework, and they often copied each other's work when they did not understand the content being taught. They typically engaged each other verbally during instruction, often shouting at each other across the classroom about topics not related to the mathematics being taught. In fact, most of these students struggled with reading and writing, which affected their ability to comprehend the mathematics being taught and to solve even simple mathematics problems; only two of the 20 had achieved the passing grade of 50% in the previous term.

These students resided within the school community and were engaged in community life. Some of them represented their school at sporting and cultural events, and many of them were from families in which members were entrepreneurs in the community, such as hair stylists, nail technicians, masons, plumbers, and labourers. Some of these students worked part-time before or after school to earn pocket change.

Data collection

The study was conducted over 10 forty-minute lessons over a three-week period from January to February 2018. In the lesson immediately preceding the first intervention lesson, the teacher described the nature of the game-based intervention in which NDLG would be integrated into each of their lessons. The teacher outlined for students the expected behaviour during lessons and emphasized the importance of students' questions and discussion about their ideas, listening to each other during group tasks and general discussions, and responding to each other without the use of offensive language. Students were allowed to ask questions about the intervention strategy. Subsequently, the teacher, with the assistance of an English teacher at the school, instructed students on the nature of the journals they would keep during the intervention, and facilitated some practice writing journal entries. Students were provided prompts on which to focus their journal entry after each lesson: how they were engaged in learning during the lesson, what they appreciated about the learning game, and what they perceived they had learned about the content during the lesson. The use of prompts in journalling allows students to express their feelings and thoughts and the teacher to determine the extent to which students perceived that they were engaged and enjoyed the lesson (Phillips & Carr, 2014). Student journals provided data about how students responded to the intervention for the first research question regarding students' perceptions of the NDLG learning environment. During each lesson, the teacher recorded her observations of the students' engagement and physical participation in learning activities in a notebook, after which she elaborated on her observation in field notes. This data allowed us to respond to the second research question regarding student engagement in learning during the intervention.

Ethical Considerations

Before the start of the research, the authors followed ethical protocols to ensure that the research was robust, and the findings were valid and reliable. Prior to implementing the intervention, the authors informed, in writing, the school's administrator, parents and students about the nature of the research, the expected outcomes, and the strategies to protect the identity of the school and students who participated in the study. The authors obtained signed informed consent from parents regarding student participation in the intervention. The authors also took steps to protect the data collected during and after the intervention, securing them on password-protected digital devices that were locked in a fire-safe receptacle. Original data from student questionnaires and journals, and the teacher's notebook were transcribed into digital form and coded to protect the identity of the school and all participants. Further, all student data was reported as group statistics to further ensure the confidentiality of participants.

The Intervention

We aligned the NDLG with the mathematics curriculum for Grade 9. The NDLG varied by lesson to introduce diversity into teaching and learning by introducing creative ways for students to use the mathematics content they learned. Each NDLG was given a catchy name to help students connect them to the specific mathematics content being taught, for example, Pi Station, Circle Memory, and Resolve the Circumstances. The teacher explained the rules of each NDLG and, where necessary, demonstrated how it should be played, but without performing the required tasks involved. Students were encouraged to ask questions about the NDLG if they were unclear about its procedure or rules. This was an important step in the process because it allowed them to understand how the NDLG were to be played, so that they could focus on playing and using the mathematical knowledge they had to complete the game. The teacher placed students into groups of four or five, based on her knowledge of their mathematical knowledge and ability, as well as the social composition of the class and students' preferences regarding work partners. This was important because a primary function of the NDLG was for students to have fun and enjoy playing with their classmates, and to cooperatively learn about the mathematics content in an environment that maximized their productivity and minimized disruptions.

Students played NDLG in teams. All teams had identical task sheets for games played during each lesson; each team member had an individual task sheet to complete during the game. Task sheets provided game rules and guidelines about engagement with each other, as well as real-life problems to solve during the NDLG. The teacher visited each group to ensure that they were playing the game correctly and following the rules, to offer support to groups that experienced difficulties during the activities, and to assess these task sheets and verify solutions. Once the NDLG was completed, the teacher and students engaged in a whole-class discussion to compare and discuss the findings of each group, and to arrive at agreed responses. Group points were tallied at the end of each lesson and teams were ranked based on the points earned. The teacher collected task sheets at the end of each lesson in order to more closely assess students' work and returned them in the following lesson.

It is important to note that much of the content taught in the unit of work required re-teaching content previously taught in Grade 8 because students simply did not recall these concepts in the assessment of prerequisite knowledge. Consequently, the specific concepts and skills addressed over the ten 40-minute lessons were "Topic 2.5.2 Circles" (Curriculum Development Division, 2014, pp. 134-135), and "Topic 3.5.1 Area and Perimeter of Compound Shapes Involving Parts of the Circle" (Curriculum Development Division, 2014, pp. 163-164) from the Grade 8 and Grade 9 Measurement strands, respectively. Although the use of NDLG as teaching, learning and assessment strategy was not indicated in the curriculum, students' background and the benefits of NDLG articulated in the research literature provided adequate support for its use in the given context. Therefore, NDLG were designed that aligned with the mathematics curriculum for Grade 9. Eck (as cited in Naik, 2014) suggested that NDLG could develop students' "ability to match concepts, manipulate numbers, and recognize patterns" (p.432). In this study, NDLG were used for learning and assessment for learning. Table 1 introduces the three NDLG on which we report in this paper, illustrating how they align with the outcomes stated in the revised mathematics curriculum (Curriculum Development Division, 2014).

Table 1

NDLG and related outcomes from the secondary school mathematics curriculum.

NDLG	Stated curriculum outcome	Suggested teaching strategies in the curriculum
Pi Station	2.5.2.2 (Grade 8) Derive the numerical value of Pi	Measure the circumference and diameter of different circles with string and ruler, then investigate the relationship between circumference and diameter (p. 134)
Circle Memory	2.5.2.4 (Grade 8) Use the formula for the circumference of a circle	Apply substitution skills to the formula $C=D$ or $C=2r$ to calculate the unknown value of the circumference, diameter, or radius of a circle (p. 135)
Resolve the Circumstances	3.5.1.3 (Grade 9) Apply formulae to determine perimeter of compound shapes involving parts of the circle	Present 2D drawings of compound shapes from the real world and have the students divide the shapes into the least number of known simple shapes including sectors (p. 164)

Description of the NDLG and Outcomes of their Implementation

In this section, the three NDLG are presented: name; target curriculum content; lesson in which it was played for contextualization; description with resources, materials, student groupings; procedures, duration, rules, and teacher and student roles; and outcomes. The outcomes in terms of students' perceptions on the NDLG learning environment and the teacher's perception of their engagement in learning activities follow the presentation of each game.

Game 1: Pi Station Game

Mathematical content. This game focused on deriving an approximate value of Pi, which was Outcome 2.5.2.2 in the Grade 8 curriculum. Although this should have been pre-knowledge for this unit of work, students did not recall the value of Pi, and had no tangible means of recalling its estimated value. Hence, it was important to allow them to derive an estimated value of Pi to aid with recall for future use.

The lesson. This game was the second lesson in ten lessons in the unit. During this 40-minute lesson, Pi Station was played for the middle twenty minutes of the lesson. Its objective was to engage students in inductive inquiry to investigate and use the relationship between the circumference and diameter of a circle to derive the numerical value of Pi. The teacher introduced the topic for the lesson and probed students' knowledge of the numerical value of Pi. She then related a short story to students that indicated how the value of Pi changed over time. Subsequently, she informed students that they would play Pi Station, during which they would use everyday objects and measuring instruments to derive an approximate value of Pi, which they would then compare to those presented in the story to determine which one was the best approximation of Pi. She provided them with the instructions and rules for playing Pi Station.

Description of Pi Station. In the classroom, the teacher used four tables to create four Pi Stations. Each station contained the same types of objects with a circular cross-section, including food cans, coins, CDs/DVDs, rolls of adhesive tape, and other similar household objects. The teacher grouped students into four teams of five, based on her knowledge of them and their indicated preferences for working with each other. Each team was provided with rulers, a measuring tape, cotton string, tracing paper, pencils, and a worksheet with game instructions and a data-entry table to complete (see Figure 1).

Object	Circumference	Length of Diameter	$\pi = \frac{\text{Circumference}}{\text{Length of Diameter}}$

Figure 1
Data-entry table for Pi Station.

Procedures for playing Pi Station. This NDLG comprised four rounds that allowed teams to explore four different objects. At the start, teams decided on a team leader and a scribe. At the start of the first round, the first player from each team retrieved one object from a station to take to their team. The teams used string to wrap around the circular cross-section of the object, which they then cut with scissors to exact length. They lay the cut string next to a ruler to measure its length, which they recorded in the circumference column on their worksheets. They used a pencil to trace the circular cross-section of the object on tracing paper provided, then folded the paper so that one half of the drawn circle overlay the other half. They traced the fold with a pencil and used a ruler to measure its length, which they recorded in the diameter column in the worksheet. Upon completion of round one, the next player returned the object to the station and selected another object and repeated the procedure completed in round one until they had measured four objects.

Once teams had entered all their measurements in the data-entry tables, they performed the division indicated in the table (see Figure 1) to determine the ratio of circumference to diameter for each object. They wrote their derived value of Pi as a fraction and a decimal. They then found the average of the four values of Pi to determine an estimate of Pi. Each team leader indicated to the teacher when they had completed their task, and the teacher recorded the order in which teams completed the task. The teacher visited each group, in sequence, to verify the accuracy of their computation, and recorded the order in which they had completed accurately. Once all teams had completed the activity, the teacher declared the winner as the first team to have computed the closest estimate of Pi. The teacher allowed teams to share their estimated values of Pi, and probed students about reasons that the value of Pi might have varied from one object to the other, and from one group to the other. Students then wrote a concluding statement in their notebooks about the relationship between the circumference and diameter length of a circle, and reasons the value of Pi is an estimated value.

Outcomes of Pi Station Game. This game aimed to derive an appropriate estimate of Pi through measurement and computing ratios. Students responded very positively to the task. In her observation notes, the teacher wrote, "The lesson started with a brief history of Pi and the students were very interested in the story". Students remarked that they had heard of Pi but had not known of its history. One student also wrote in her journal that she "enjoyed hearing the story of Pi". Some students questioned why Pi was "invented", which the teacher used as an opportunity to assign them the task of researching it to present in the subsequent lesson. Although two students struggled to use the material provided for them for the measurement activity, the teacher noted that "weaker students were more involved in this game", and surmised that "it required their psychomotor skills to be used". Students had not demonstrated dexterity in handling the tools, which is not surprising because of lack of practice in using measuring instruments and engaging in measuring exercises prior to the unit of work. Despite the challenges involved in measuring the objects, students wrote in their journals that they enjoyed "measuring and calculating Pi", and that they valued working together and "helping [their] teammates" to compete against other teams. All teams were able to complete their tables. Overall, students deduced that discrepancies among the values of Pi were due to measurement error rather than computational error. In the end, students agreed that 3.142 was a reasonable approximation for Pi.

The teacher noted that although the classroom was very noisy as students played the game, the noise resulted from excitement during gameplay rather than from indiscipline and disruptive behaviour. She wrote that "students were very elated and excited to complete this game". Students were not shouting across the classroom at students in other groups, but were genuinely excited about completing their tasks ahead of other teams. For the duration of the game, they all demonstrated on-task behaviour as they cooperated to complete the task, taking turns when appropriate. None of the students were observed to be distracted from the task, falling asleep or distracting other students during gameplay. The teacher noted an unexpected outcome of the interaction among students, namely that some students naturally emerged as group leaders during gameplay. At the end of this particular lesson, the teacher wrote: "I also noticed that leadership qualities seemed to be a recurring trait in some students". She noted that some students who were typically quiet and not engaged in learning, emerged as team leaders during the game. She was satisfied with the lesson outcomes. She wrote: "Overall, the lesson was very successful and the students really enjoyed the game today".

This lesson provided the foundation for the subsequent lesson in which students would derive the circumference formula ($C = d\pi$) from the relationship between the circumference and diameter length of a circle. By extension, they would derive the circumference formula involving the radius length ($C = 2r\pi$) by using the relationship between the diameter and radius lengths.

Game 2: Circle Memory

Mathematical content. This game focused on computing the perimeter of semicircles and quarters, which was Outcome 2.5.2.4 in the Grade 8 curriculum. Pre-assessment also revealed that students struggled with applying and transposing the circumference formula to problem solving, particularly where problems involved the perimeter of semicircles and quarter circles. Hence, this lesson targeted these skills in preparation for the Grade 9 curriculum content.

The lesson. This NDLG was played during the sixth lesson. The objective of the lesson was to engage students in an inductive inquiry to derive strategies for computing the perimeter of semicircles and quarter circles and to apply the circumference formula accurately. During this 40-minute lesson, the NDLG was played in the third 10-minute block of the lesson. The teacher showed students photos of quarter of a pizza and half of a pizza and probed them about the names of these shapes. She probed them about how they would find the length of the arcs of these shapes, and then introduced the topic of computing the perimeter of these shapes. Students worked in pairs to fold and cut paper circles to create semicircles and quarter circles and to determine their relationship with their relative circles (halves or quarters, respectively). They then worked together in small groups of four to explore the components of their perimeters and to devise a strategy for computing the perimeter of these shapes. Students planned several strategies which they represented by $P = \frac{1}{2} d\pi + 2r$ or $P = r\pi + d$ to compute the perimeter of semicircles, and $P = \frac{1}{4} d\pi + 2r$ for quarter circles. The teacher accepted these formulae without attempting to use factorization to simplify or restate them otherwise. Students were provided with opportunities to practise applying their strategies in practice exercises.

Description of Circle Memory. Students worked in teams of five to play a modified memory card game called Circle Memory; pairs of teams competed against each other. The teacher created 2-inch by 3-inch playing cards from Bristol board. On the back of the cards was written Circle Memory; on the front of the card was an illustration of a semicircle with its diameter or radius length or a quarter circle with its radius length, or a given perimeter to be matched (see Figure 2). The objective of the NDLG was to match the illustration to its perimeter. There were some cues to assist students, including the measurement units; there was no conversion between units used in this game in order to avoid introducing unnecessary complexity this early in skills acquisition.

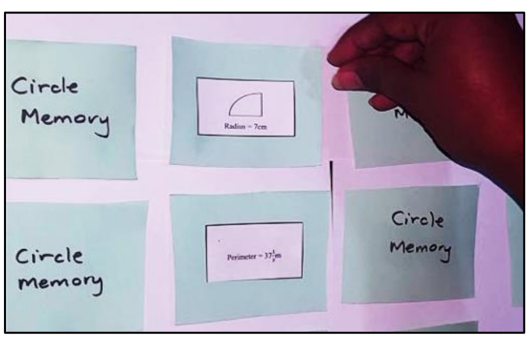


Figure 2
Playing cards for Circle Memory game.

Procedure for playing Circle Memory. As with the memory card game, all cards were laid across a table with the Circle Memory side facing up. One player from each team took a turn to select two cards and turn them face up on the table without changing their original positions. Players had a scratch pad, pencils, their notebooks and calculators to compute the perimeters in 30 seconds, with the support of their teammates. To determine whether the pair of cards matched, both teams had to agree on the accuracy of the calculation and could call on the teacher to verify the answer. If the pair of cards matched, then the player added them to the group's stack, and another player from the same team took a turn until a pair of non-matching cards was turned up. If the pair of cards did not match, then the player turned them over in their original position, and the next group took a turn. The game ended when all the cards were matched. The team with the most cards was declared the winners.

Outcomes of Circle Memory Game. This NDLG targeted recall and application of the formulae they devised in the previous lesson to accurately match the circumference of circles and the perimeters of quarter circles and semicircles with appropriate radii and diameters. Students responded very positively to this NDLG. In her observation notes, the teacher wrote: "Of all the games played in the lessons so far, this one was the most enjoyed. The students were excited to be in groups and excited to try to win". They were noisy, but the noise was productive rather than disruptive noise, indicative of students' enjoyment in playing. Students wrote in their journals about feeling "joyful", of playing the game being "exciting", of having "fun", of "working together as a team", and of enjoying "the competition" that the game offered. The teacher also noted that this NDLG encouraged all students to engage with each other and the content. She wrote: "The Circle Memory game ... encouraged them to participate throughout the lesson". This is supported by students' journal entries, with one student writing: "I participated by saying answers/working in groups". The teacher also noted that students appeared to value working together to complete tasks in a competitive environment.

Working in teams was critical for success in this NDLG because it was more challenging than the previous ones, requiring students to compute perimeters using strategies they had learned in that lesson. The teacher noted that students remained on task and, "were very eager to find the solutions so that they could match the cards". About their interactions during gameplay, the teacher wrote: "For the most part, the game remained orderly with students working extremely well in their groups. The team spirit and collaboration amongst the students were very heartening". Further, similar to the Pi Station game, playing this NDLG supported student leadership. The teacher wrote: "I noticed with interest that the activity brought out leadership qualities in some of the students, especially [*Henry*]." Henry (pseudonym) was generally a quiet boy who was usually attentive during lessons, but contributed very little. He seldom completed tasks or homework. However, during these NDLG, Circle Memory in particular, Henry consistently tried to encourage his teammates to persist with the task and to work together to solve the problems. As she concluded her notes about this NDLG, the teacher noted: “Games that require students to work in groups have proven to really work for this class because they were able to pull their abilities together to achieve one common goal which was winning the game”.

Overall, the teacher believed that this NDLG helped students to “successfully grasp the concepts taught and ... reinforce the keywords such as diameter, perimeter, semi-circle and quarter-circle”. This was a critical outcome of this NDLG because these skills provided the foundation for the subsequent lesson in which students would devise strategies for computing the perimeter of compound shapes comprising semicircles and quarter circles.

Game 3: Resolve the Circumstances

Mathematical content. This game focused on computing the perimeter of compound shapes, which was Outcome 3.5.1.3 in the Grade 9 curriculum. This content required students to apply the circumference formula to compute the perimeter of compound shapes that included semicircles and quarter circles.

The lesson. This was the final lesson of the unit – lesson 10. The objective of this lesson was to engage students in thinking about and solving simple authentic problems related to computing the perimeter of a compound two-dimensional shape involving semicircles. Therefore, students had to first decompose given compound shapes into the least number of constituent plane shapes. The foundation for this activity was established in the previous lesson. During that lesson, pairs of students were provided with cardboard cut-outs of squares, triangles, semicircles and rectangles. They were instructed to identify and trace their fingers along the perimeter of these shapes, noting the number of edges and curves that comprised each one. They were then instructed to use the cut-outs to create a compound shape so that the cut-outs did not overlap or have spaces between them, and that each was alongside at least one other cut-out to form the compound shape (see Figure 3).

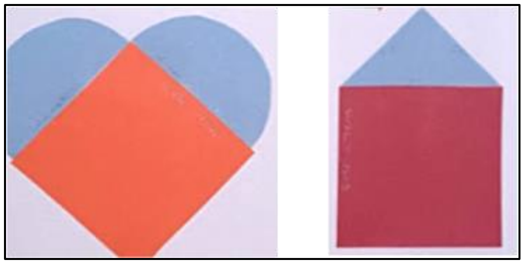
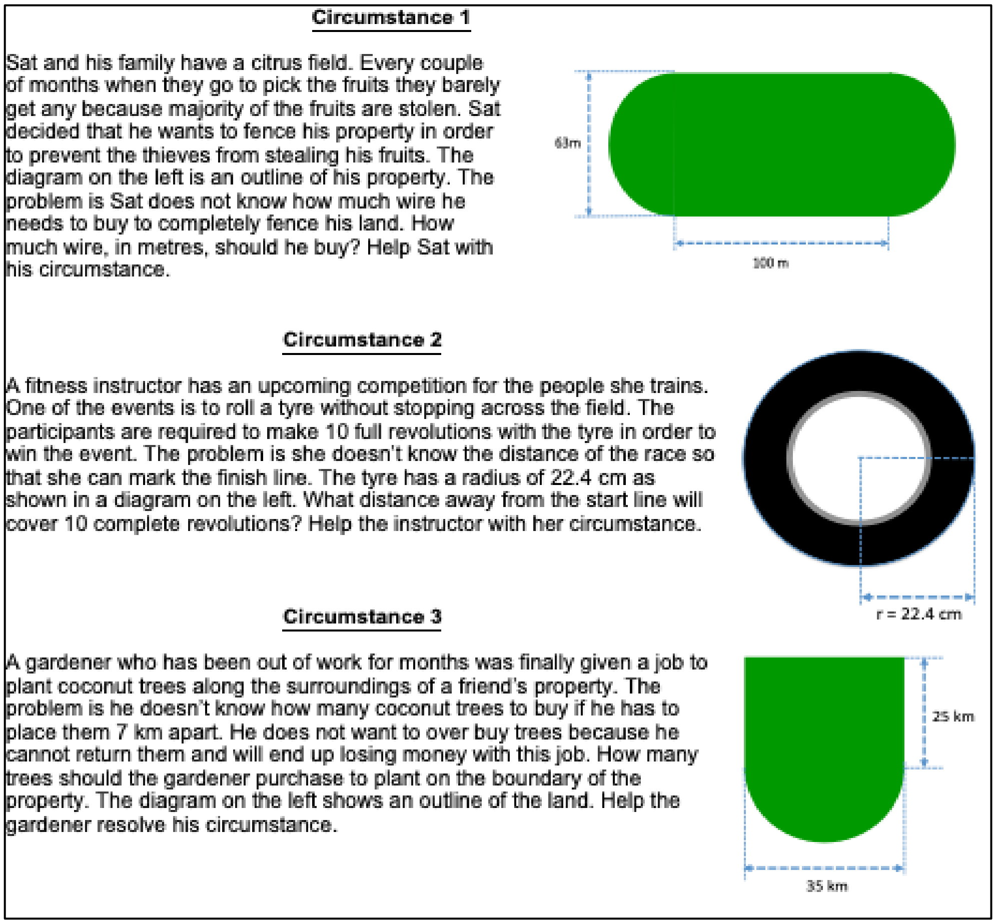


Figure 3
Compound shapes from cardboard cut-outs.

They traced around their compound shapes in their notebooks, including their constituent cut-outs, and traced their fingers around the perimeter, paying attention to the edges and curves. They recorded their observations about the constituent shapes of their compound shapes and any edges of the cut-outs that were not included in the perimeter of the compound shape. They described their strategy to determine the perimeter of their compound shape. At the end of the lesson, they shared their compound shapes with the class and explained how they might determine its perimeter. They agreed that the sum of the outer edges and curves of the simple plane shapes was equivalent to the perimeter of the compound shape.

At the start of the final lesson, the teacher probed students about these ideas which they had shared in the previous lesson, because it was the foundation of the current lesson. Students noted that when they formed compound shapes using plane shape cut-outs, some edges of the cut-outs were not part of the perimeter. They also restated the strategy they derived for computing the perimeter of the compound shape in the previous lesson. These ideas provided the foundation for problem solving in the final lesson through the Resolve the Circumstances game.

Description of Resolve the Circumstances. Students worked in teams of four to play this NDLG for 30 minutes. Gameplay was preceded by a five-minute recap of their pre-knowledge from the previous lessons, and followed by a five minute consolidation of the strategies they had used for problem solving. The game was a problem-solving exercise that was intended to help students link the mathematics they learn in school to the mathematics used in daily life. In other words, the NDLG was designed to address the lesson objective of solving simple authentic problems involving the perimeter of compound shapes that included semicircles. Students were required to decompose compound shapes into the least number of constituent plane shapes, identify the edges and curves that comprised the perimeter, and then compute the perimeter. These problems increased in complexity from the first to the last, and are presented in Figure 4.



Circumstance 1

Sat and his family have a citrus field. Every couple of months when they go to pick the fruits they barely get any because majority of the fruits are stolen. Sat decided that he wants to fence his property in order to prevent the thieves from stealing his fruits. The diagram on the left is an outline of his property. The problem is Sat does not know how much wire he needs to buy to completely fence his land. How much wire, in metres, should he buy? Help Sat with his circumstance.

Circumstance 2

A fitness instructor has an upcoming competition for the people she trains. One of the events is to roll a tyre without stopping across the field. The participants are required to make 10 full revolutions with the tyre in order to win the event. The problem is she doesn't know the distance of the race so that she can mark the finish line. The tyre has a radius of 22.4 cm as shown in a diagram on the left. What distance away from the start line will cover 10 complete revolutions? Help the instructor with her circumstance.

Circumstance 3

A gardener who has been out of work for months was finally given a job to plant coconut trees along the surroundings of a friend's property. The problem is he doesn't know how many coconut trees to buy if he has to place them 7 km apart. He does not want to over buy trees because he cannot return them and will end up losing money with this job. How many trees should the gardener purchase to plant on the boundary of the property. The diagram on the left shows an outline of the land. Help the gardener resolve his circumstance.

Figure 4
Authentic problems for the Circle Memory game

Procedures for playing Resolve the Circumstances. Each student received a copy of the problem sheet with three circumstances to resolve. All students were allowed to write their individual solutions in their notebooks, but each team must have agreed on an answer and justified it. The circumstances increased in complexity from the first to the last stage. Upon solving each problem the team would shout, "circumstance resolved". Once the teacher verified the answer, the stage was completed and the team progressed to the next level. If the answer was inaccurate, the team revisited the problem with some assistance from the teacher who provided one hint. The first team to resolve all three circumstances was declared the winners.

Outcomes of Resolve the Circumstances Game. This NDLG targeted problem solving involving the perimeter of shapes with quarter circles and semicircles. The teacher noted that the NDLG was designed to allow students to solve problems that people deal with every day. The teacher wrote: "Students really enjoyed the discussion about circumstances and were surprised to learn how circumference can be used to resolve certain circumstances". In this NDLG, the teacher noted that students worked extremely well in teams, and that it was the most organized game in the unit: "The game was well played and it was clear that students enjoyed working in groups". She also noted that in this game, as in the two previously reported above, typically quiet and reserved students emerged as leaders within groups, which helped increase the level of participation and reduce the number of disagreements. She wrote: "I was so proud of my students to see that they could work together without any argument so that they could be victorious in the game being played".

However, this NDLG was the most challenging for students. Although students could compute the perimeters to eventually solve the problems, they experienced great difficulty getting to that point without the teacher's intervention. Teams were unable to independently analyse the text-based problems because of poorly developed reading comprehension skills. Students wrote in their journal entry about needing to "depend on each other" to complete this game. The teacher noted that "students couldn't understand the problems. They could read most of the words on their own but they couldn't put them together to make sense of the sentences". For the first problem, when the teacher had to visit each team to help them read and analyse it, she changed the strategy. She engaged the whole class in analysing each problem and then allowed teams to solve it independently. As each team solved the problem and shouted, "Circumstance resolved", she verified their response and noted the sequence in which teams completed each problem. Consequently, this game required 40 minutes to complete, and although gameplay was extended into the lunch period, students remained enthusiastic to play during their lunch break until they had solved all the problems. Students also wrote in their journals that they needed "all team members to work together" to solve the problems because they were the most difficult ones in the unit. Despite the challenge, they did not appear discouraged, but were resolute in their desire to solve all the problems before other teams.

SYNTHESIS OF FINDINGS AND DISCUSSION

Overall, the aforementioned findings about the outcomes of the three lessons in which these NDLG were played suggest that the mathematics classroom had been transformed into a learning environment that actively engaged students in learning mathematics. This conclusion is grounded in data collected from students' behaviour, including their increasing enthusiasm during gameplay, cooperation and interaction within groups, their favourable remarks about their experiences in their journals, and the teacher's observation notes about the nature of the lessons.

It has already been established that meaningful engagement in learning mathematics is a pre-requisite to students developing positive attitudes towards mathematics, mathematical knowledge and conceptual understanding, mathematics self-efficacy, and mathematical thinking and problem-solving skills. There is evidence in the outcomes of the three NDLG presented in this paper that suggests that students were engaged in learning mathematics during the three lessons. For example, by the time students played Pi Game in the second lesson, they had begun to associate learning mathematics with having fun and appeared to derive much enjoyment from cooperating with their teammates on completing the game task. The learning environment in the classroom engaged students in social learning through NDLG that was designed to align with their backgrounds and interests, to capture their imagination, interest and experiences, and to engage them in mentally stimulating and challenging fun-learning activities; these are factors that Vygotsky (1978) and Lave and Wenger (1991) suggested were imperatives of the learning environment. Bragg (2007) and Tosto et al. (2016) all agreed that a positive learning environment could improve student learning outcomes in mathematics, which was evident in this mathematics classroom. In Circle Memory and Resolve the Circumstances students were better equipped and mentally prepared to work together with teammates and to compete against other teams, and even when they experienced challenges in the problem solving in the latter game they encouraged each other and persisted with the task well into the lunch break.

During Resolve the Circumstances students struggled with its heavily text-based nature that required them to read and analyse story problems, although these problems were accompanied by illustrations. Reading for comprehension is a prerequisite for mathematical problem solving and struggling readers can be disenfranchised if teachers do not accommodate their needs during instruction. Fortunately, despite the challenges and the teacher's intervention in the game, students demonstrated emotional commitment to their teammates to complete the tasks. This outcome could support the assertion of Ayers et al.

(2005) about the positive effect of increased student interaction during learning on feelings of connectedness with others. The learning environment encouraged social interaction and engagement inquiry, discussion, negotiations and cooperation within teams, which appealed to the socialization needs of students as Boiselle (2014) suggested, especially those who were usually socially withdrawn. As Hromek and Roffey (2009) suggested, it was evident from these findings in this mathematics classroom that the social context of learning should attend to students' wellbeing, emotional management, and connectedness. This is an important outcome that can be associated with Vankúš' (2008) suggestion about the importance of designing games to match students' knowledge and abilities as an educational imperative. It must be noted that despite the challenges students encountered, they abided by the rules of the games, which resulted in a much more manageable classroom. This was testimony to the didactic potential in this mathematics classroom of learning games that Vankúš (2008) purported, and is especially important for these students who were considered as low-achieving.

Besides having fun and enjoying the lessons, students needed to cooperate with each other during inquiry tasks in order to overcome the challenges. The competitiveness among the teams provided them with stimuli that motivated them to learn mathematics and develop their conceptual understanding and mathematical problem solving, outcomes that Backlund and Hendricks (2013), Bragg (2007; 2012), Davies (1995), Hromek and Roffey (2009), and Paniagua (2015) identified as benefits for students. It was evident from one lesson to the next that students could recall the value of Pi from Pi Stations through the tactile experience of measuring familiar circular objects. They could also recall and apply the circumference formula in Circle Memory through an adaptation of a memory game that many children play, and apply the circumference formula in Resolve the Circumstances through discussion and negotiation to solve simple authentic problems that were contextually relevant. Among this group of students, these findings support those reported by Rathva (2012) about the role of learning games in strengthening students' recall and mathematics confidence. Additionally, these NDLG provided what Harris et al. (2001) identified as meaningful scaffolds to learning mathematics and developing problem- solving skills because the NDLG were well organized, mathematically rich, inquiry-based activities that presented students with stimulating and challenging problems. These outcomes reflect the ideas of Kapp (2012), Rossiter (2007), Rutherford (2015), Skotinos (2017) and Vankúš (2008) who touted the view that when learning games are designed for a specific purpose and for a specific group of students, they build on students' existing knowledge and experiences to develop their conceptual understanding, higher-order thinking skills, and other skills through discussion, practice and mental engagement.

It was noted that although student teams were offered no rewards for winning these NDLG, they all played with enthusiasm and with determination to beat other teams in completing the task. On the surface, this finding appears insignificant because students were having fun and enjoying the NDLG. However, this is a critical element of success in integrating NDLG into instruction. As Kapp (2012) pointed out, the satisfaction of overcoming challenges and the social interaction that games offer are more important to children than any rewards. The absence of a high-stakes reward for victory created a safe and non-threatening learning environment for students in which they could play, solve problems and learn together.

CONCLUDING REMARKS

In this paper, we presented selected outcomes integrating three learning NDLG into mathematics instruction in a Grade 9 mathematics classroom at one government secondary school in Trinidad and Tobago. The study interrogated how these NDLG affected students' perceptions of the NDLG learning environment and the teacher's perception of students' engagement in learning mathematics, in order to address concerns about low student engagement in learning mathematics and poor mathematics achievement among students in this class. We identified NDLG as an intervention based on the research literature on the potential of using games as a didactic strategy. Students responded favourably to the change in the learning environment resulting from integrating NDLG into instruction, and demonstrated this through the active participation and engagement in learning during lessons in which these NDLG were played. They enjoyed playing and solving mathematics problems together, as well as the competitive nature of these NDLG, even when facing challenges.

Although these findings are localized to one school in Trinidad and Tobago, we are hopeful that other mathematics educators will utilize these tangible examples of how simple NDLG can be designed to align with mathematics curriculum objectives and integrated into mathematics instruction. More research into the other potential benefits of NDLG in the Trinidad and Tobago context at all levels from early childhood to tertiary is necessary to arrest the decline in mathematics achievement by making learning mathematics more interesting and engaging to students. These findings also suggest that NDLG can be inexpensively created or adapted from any traditional games and include everyday objects in their design and execution. This is a viable active learning strategy that teachers can use in any classroom that is not technology-equipped and in any school without the required infrastructure to support digital games.

REFERENCES

Abdul Jabbar, A. I., & Felicia, P. (2015). Gameplay engagement and learning in game-based learning: A systematic review. *Review of Educational Research, 85*(4), 740-779.

Ayers, L. R., Beyea, S. C., Godfrey, M., Harper, D. C., Nelson, E. C., & Batalden, P. B. (2005). Quality improvement learning collaboratives. *Quality Management in Health Care, 14*, 234-247.

Attard, C. (2012). Engagement with mathematics: What does it mean and what does it look like? *Australian Primary Mathematics Classroom, 17* (1), 9-12.

Backlund, P., & Hendrix, M. (2013). *Educational games – are they worth the effort? A literature survey of the effectiveness of serious games.* 2013 Fifth International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES) (pp. 1-8). IEEE. https://core.ac.uk/download/pdf/30618517.pdf

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., Krathwohl, D. R. (1956). *Taxonomy of educational objectives, Handbook I: The cognitive domain*. David McKay.

Boiselle, L. N. (2014). Online-learning and its utility to higher education in the Anglophone Caribbean. *SAGE Open, 4*, 1-14.

Bragg, L. (2007). Students' conflicting attitudes towards games as a vehicle for learning mathematics: A methodological dilemma. *Mathematics Education Research Journal, 19* (1), 20-44.

Bragg, L. (2012). Testing the effectiveness of mathematical games as a pedagogical tool for children's learning. *International Journal of Science and Mathematics Education, 10* (6), 1445-1567.

Bruner, J. (1961). The act of discovery. *Harvard Educational Review, 31*(1), 21.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed method research* (2nd ed.) SAGE.

Curriculum Development Division, Trinidad and Tobago. (2014). Secondary school curriculum: Mathematics.

http://moe.gov.tt/Portals/0/Documents/Secondary/9%20SCR%20Mathematics%20Curric

Davies, B. (1995). The role of games in mathematics. *Square One, 5* (2), 7-17.

Dewey, J. (1938). 1997. *Experience and education*. Macmillan.

Dofková, R., & Uhlířová, M. (2016). Next generation classroom as an instrument for motivation in mathematics. *INTED 2016 Proceedings*, 3178-3183.

Gettinger, M., & Walter, M. (2012). Classroom strategies to enhance academic engaged time. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 653-673). Springer.

Gyöngyösi, E. W. (2012). Teaching and learning mathematics through games and activities. *Acta Electrotechnica et Informatica, 12* (3), 23-26.

Hamari, J., Schernoff, D. J., Rowe, E., Coller, B. K., Asibel-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior, 54*, 170-179.

Harris, K., Marcus, R., McLaren, K., & Fey, J. (2001). Curriculum materials supporting problem-based teaching. *School Science and Mathematics, 101*(6), 310-318.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16* (3), 235-266.

Hromek, R., & Roffey, S. (2009). Promoting social and emotional learning with games: "It's fun and we learn things". *Simulation & Gaming, 40* (5), 626-644.

Jaggernauth, S. J., Ramsawak-Jodha, N., Kamalodeen, V. J., Dedovets, Z., Barrow, D. A., & Figaro-Henry, S. (2019). Exploring gamification for reinforcing geometrical concepts and skills at the primary level in Trinidad: A mixed methods pilot study. *Caribbean Curriculum, 26*, 65-98.

Kalloo, R., Jaggernauth, S. J., Ramsawak-Jodha, N., Kamalodeen, V. J., Sabeerah Abdul-Majied, Dedovets, Z., Barrow, D. A. & Figaro-Henry, S. (2019). An exploratory study of game-based approaches in primary mathematics and science classrooms in Trinidad and Tobago. *Journal of Education and Development in the Caribbean, 18* (1), 30-81.

Kapp, K. (2012). *The gamification of learning and instruction: Game-based methods and strategies for training and education*. Pfeiffer.

Karigi, M.W. & Tumuti, S. (2015). Students and teachers attitude factors contributing to poor performance in mathematics in K.C.S.E. in selected public secondary schools in Kiambaa Division of Central Province, Kenya. *Strategic Journal of Business and Change Management, 2* (58), 316-332.

Klopfer, E., Osterweil, S., & Salen, K. (2009). *Moving learning games forward: Obstacles, opportunities & openness*. The Education Arcade.

Laird, A., & Grootenboer, P. (2018). Designing data collection instruments to research engagement in mathematics. In J. Hunter, P. Perger, & L. Darragh, (Eds.), *Making waves, opening spaces*. Proceedings of the 41st annual conference of the Mathematics Education Research Group of Australasia (pp. 471-478). MERGA.

Lave, J. (1988). *Cognition in practice: Mind, mathematics, and culture in everyday life*. Cambridge University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Lincoln, Y., & Guba, E. (1985). *Naturalistic inquiry*. SAGE.

Martin, A., & Marsh, H. (2006). Academic resilience and its psychological and educational correlates: A construct validity approach. *Psychology in the Schools, 43* (3), 267-281.

Massey, A. P., Brown, S. A. & Johnston, J. D. (2005). It's all fun and games…until students learn. *Journal of Information Systems Education, 16* (1), 9-14.

Mata, M., Monteiro, V. & Peixoto, F. (2012). Attitudes towards mathematics: Effects of individual, motivational, and social support factors. *Child Development Research, 49* (1), 1-10.

McGonigal, J. (2011). *Reality is broken: Why games make us better and how they can change the world*. Penguin.

Mustafa, J., Khan, A. & Ullah, A. (2011). Investigating students' achievement in mathematics through non technological game-based teaching. *International Journal of Scientific Research in Education*, *4* (3-4), 151-164.

Naik, N. (2014). Non-digital game-based learning in the teaching of mathematics in higher education. In C. Busch (Ed.), *European conference on games based learning,* (vol. ii, pp. 431-436). AcademicConferences Ltd.

Namukasa, I. (2004). School mathematics in the era of globalization. *Interchange*, *35* (2), 209-227.

National Council of Teachers of Mathematics (NCTM). (2014). Access and equity in mathematics education: A position of the National Council Of Teachers Of Mathematics. https://www.nctm.org/uploadedFiles/Standards_and_Positions/Position_Statements/Access_and_Equity.pdf

Oldfield, B. (1991). Games in the learning of mathematics – Part 2: Games to stimulate mathematical discussion. *Mathematics in School*, 7-9.

Paniagua, F. (2015). *Engaging students in class activities through games to increase participation*. Cengage Learning.

Patton M. Q. (2002). *Qualitative research and evaluation methods (3rd ed.)*. SAGE.

Phillips, D. K., & Carr, K. (2014). *Becoming a teacher through action research: Process, context, and self-study*. Routledge.

Prensky, M. (2001). *Digital game-based learning*. McGraw-Hill.

Radloff, A. & Coates, H. (2010). *Doing more for learning: Enhancing engagement and outcomes: Australasian survey of student engagement*. *Australasian student engagement report*. Australian Council for Educational Research (ACER). https://research.acer.edu.au/cgi/viewcontent.cgi?article=1011&context=ausse

Rathva, P. (2012). *Teaching mathematics through activities*. http://www.ncert.nic.in/pdf_files/TEACHING%20MATHEMATICS(Parul%20Rathva).pdf

Rossiter, A. (2007). *Using games in mathematics teaching.* Department of ACSE, University of Sheffield.

Rutherford, K. (2015). *Why play math games?* National Council of Teachers of Mathematics. http://www.nctm.org/publications/teaching-childrenmathematics/blog/why-play-math-games /

Schoenfeld, A. H. (1988). When good teaching leads to bad results: The disasters of "well-taught" mathematics courses. *Educational Psychologist*, *23*, 145-166.

Shute, V. J., Rieber, L., & Van Eck, R. (2011). Games … and … learning. In R. Reiser & J. Dempsey (Eds.), *Trends and issues in instructional design and technology* (33rd ed.), (pp. 321-332). Pearson.

Skotinos, A. (2017). M*athematics and the role of games in learning and teaching – Why using games in learning mathematics? The math-games methodology.* European Erasmus Project Math-Games: http://www.vmsmedien.de/mathgames/images/methodology.pdf

Sullivan, P., & McDonough, A. (2007). Eliciting positive student motivation for learning mathematics. In J. Watson & K. Beswick (Eds.), *Proceedings of the 30th annual conference of the mathematics education research group of Australasia* (pp. 698-707). MERGA.

Sullivan, P., Mousley, J., & Zevenbergen, R. (2006). Teacher actions to maximize mathematics learning opportunities in heterogeneous classrooms. *International Journal of Science and Mathematics Education*, *4* (1), 117-143.

Sun, J. & van Es, E. A. (2015). An exploratory study of the influence that analysing teaching has on preservice teachers' classroom practice. *Journal of Teacher Education, 66* (3), 201-214.

Tosto, M. G., Asbury, K., Mazzocco, M. M., Petrill, S. A., & Kovas, Y. (2016). From classroom environment to mathematics achievement: The mediating role of self-perceived ability and subject interest. *Learning and Individual Differences*, *50*, 260-269.

Vankúš, P. (2008). Games-based learning in teaching of mathematics at lower secondary school. *Acta Didactica Universitatis Comenianae*, 103-120.

Vankúš, P. (2013). *Didactic games in mathematics*. Faculty of Mathematics, Physics and Informatics, Comenius University.

Vygotsky, L. S. (1976). Play and its role in the mental development of the child. In J. S. Bruner, A. Jolly, & K. Sylvia (Eds.), *Play: Its role in development and evolution* (pp. 537-554). Basic Books.

Vygotsky, L.S. (1978). *Mind in Society: The development of higher psychological processes* (edited by M.Cole, V. John-Steiner, D. Scribner & E. Souberman). Harvard University Press.

Whitton, N. (2012). The place of game-based learning in an age of austerity. *Electronic Journal of e-Learning, 10* (2), 249-256.

Wiersum, K. (2012). Teaching and learning mathematics through games and activites. *Acta Electrotechnia et Informatica, 12* (3), 23-26.

Wood-Jackson, A., Mahabir, C. & John, L. (2008). "The best thing created since sliced bread…" – Our journey toward blended learning. In G. Richards (Ed.), *Proceedings of world conference on e-learning in corporate, government, healthcare, and higher education 2008* (pp. 1392-1397). AACE.