The Effects of Non-Digital Game-Based Learning and Cognitive Level of Questions on Isometric Transformations

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Abstract: The present study examined the effects of the non-digital game-based instructional method and the cognitive level of questions in determining students' achievement in mathematics, particularly in Isometric Transformation. The study used a quasi-experimental design and involved 116 participants (i.e., form two students) from two local secondary schools in Kuching. The participants were divided into control and experimental groups – the control group learned the Isometric Transformation topic via conventional learning, while the experimental group used non-digital game-based learning (NDGBL). The results showed that participants who learned using the NDGBL scored better in the Isometric Transformation test than those who learned the topic using the conventional instructional method. The present findings also showed that participants' achievement of Isometric Transformation differed significantly between cognitive levels of questions. In particular, participants' achievements were recorded better for lower-level cognitive questions than higher-level cognitive questions. However, there was no significant interaction effect between the instructional method and the cognitive levels of questions on participants' achievement in the topic learned. The study provided empirical evidence on the role of NDGBL in learning Isometric Transformation, in that it should be considered as an alternative approach for learning Isometric Transformation and Mathematics in general, with an effective integration into the secondary mathematics curriculum.

Keywords: Game-Based Learning, Conventional Learning, Isometric Transformations, Students' Achievement, Thinking Skills

1. Introduction

One of the essential topics of Mathematics covered in the primary and secondary school national curriculum is Isometric Transformation, which comprises translation, reflection and rotation. Isometric Transformation is a vital topic in Mathematics that should be taught in schools at all levels (Aktas & Unlu, 2017; Division of Curriculum Development, 2016; Edwards, 2003; National Council of Teachers of Mathematics, 2000). Mastering Isometric Transformation allows students to understand other important mathematical concepts such as functions and congruence (Hollebrands, 2003). According to Febrian and Perdana (2018), a conventional learning method used by teachers, such as directly introducing to students the concept of transformation without relating to everyday life phenomena, makes it difficult for students to build their understanding. Using this conventional learning method, both teachers and students need a longer time to draw the diagrams using geometric tools to show the relatively complex transformation process (Noto et al., 2019). For example, Luneta's (2015) study of the analysis of a thousand transcripts of mathematical answers of twelfth-grade (17 years) students in

Africa found that the conceptual understanding involving translation, reflection, and rotation is still feeble. Focussing on effective learning, Luneta (2015) associated this situation with the learning strategies used in the classroom.

Recognising the importance of Isometric Transformation has led researchers to further examine the effectiveness of various instructional methods to learn Isometric Transformation (Bordewyk, 2016; Febrian & Perdana, 2018; Leong & Lim-Teo, 2003; Mashingaidze, 2012). Akay (2011) emphasised the role of active learning in learning transformation geometry. In particular, Akay (2011) observed that peer learning or collaborative learning, which involves meaningful interaction among students, was helpful in enhancing students' understanding of the concept of transformation geometry. It is also argued that using specific software to learn the Isometric Transformation topic can promote active learning, hence improving students' motivation and performance compared with using a conventional learning method (Guven, 2012; Li, 2017). Akgul (2014) observed that participants' learning of geometry transformation using interactive GeoGebra activities resulted in active and engaged student-centred learning, hence improving their achievement in the Isometric Transformation topic. Chang and Bhagat (2015) also observed the benefit of GeoGebra activities over a conventional instructional method in improving students' achievement in the Isometric Transformation topic, especially in finding the angle of rotation and direction of objects. In another study, Mashingaidze (2012) used a graphical approach to replace the algebraic approach in the learning of Isometric Transformation and found that the algebraic approach made it difficult for the students to master the concept of Isometric Transformation because it did not involve a practical-graphical approach. Further, Aliustaoglu and Tuna (2018) observed that the students' performance on Isometric Transformation was noticeably better when taught using the 4MAT approach (four learning styles–imaginative, analytic, common-sense, dynamic) than when the conventional learning method was utilised. They argued that the 4MAT approach improved the retention of knowledge of Isometric Transformations. Previous findings indicated that active learning seems to contribute toward better learning of Isometric Transformations.

Another alternative approach that has been recently considered by teachers and instructors in creating active learning is the non-digital game-based learning (NDGBL) approach. The NDGBL approach involves elements such as fun, exploration and active experience for advancing significant learning through features such as test, interest, self-articulation, disclosure, prompt input, clear objectives, player control, coordinated effort, rivalry, low reward and risk (Ke et al., 2015). A typical NDGBL approach uses existing physical game models such as cards, dice, board games, or innovation from the teachers themselves. In the NDGBL approach, solving problems or tasks during the game is one form of reinforcement that gives the students freedom in planning strategies, and exploring and finding solutions without intervention from the teacher (Park & Lee, 2017). With more tasks or missions completed by students in a game, the more likely skills are to be mastered by students. The NDGBL approach gives a clear presentation of specific processes and activities involving a task whereby these processes and activities will be performed manually by the player, thus giving them the exposure to how things are done in the real world (Radzi et al., 2017). The NDGBL approach encourages students' critical thinking and provides an opportunity for teachers and students to discuss how to improve the game in terms of rules and ways of playing to add elements of fun, challenge and competition (Hromek & Roffey, 2009). In contrast, conventional learning uses the 'chalk and talk' approach whereby the teacher delivers the content and students are later asked to analyse information in the textbook while doing drill activities as reinforcement (Nair et al., 2014).

Comparing digital game-based learning (DGBL) and NDGBL, Fang et al.'s study (2016) found significant differences between digital and traditional board games. It was reported that traditional Monopoly board games became the students' choice and was seen to be able to improve social interaction between students, compared to Monopoly games in digital form. According to Fang et al. (2016), students felt more familiar, sympathetic, and satisfied when playing Monopoly board traditional games. Rahutami et al. (2019) further indicated that direct contact (visual, speech, body) in NDGBL affects the player more than just speech/audio contact in DGBL. Hence, in terms of considering societal factors, critical thinking, cooperation, communication and respect for opponents, NDGBL was better than DGBL (Rahutami et al., 2019). In general, the findings from past studies found that NDGBL improved performance by providing a more enjoyable and active learning environment. Apart from creating an engaging learning environment, a well-planned NDGBL approach can improve interaction skills, teamwork, investigative skills, information evaluation and decision making (Chung et al., 2017).

Past studies have been conducted to study the role of the NDGBL approach in various subjects such as English grammar (Cesur, 2019), biology (Ramly et al., 2017), chemistry (Bankole, 2016) and accounting (Junaidah et al., 2016), and the benefits of NDGBL have been confirmed in those studies. In the context of Mathematics learning, several studies have also been conducted to investigate the effectiveness of NDGBL for learning various topics/subtopics in Mathematics, such as algebra (Michael & Anugwo, 2016), geometric shapes (Chung et al., 2017), geometry lines (Busadee & Klieosinak, 2016), numbers (Elofsson et al., 2016; Scalise et al., 2020), and measurement of angles (Vitoria & Ariska, 2020). Specifically, the NDGBL method was found to introduce a fun and meaningful learning process which enhanced the high school students' interest, participation and achievement in learning geometry lines in Busadee and Klieosinak's (2016) study (e.g., using cards to learn basic geometry) and in learning geometry shapes in Chung et al.'s study (2017) (using board games). Vitoria and Ariska (2020) found that the primary school students' understanding of the measurement of angles for two-dimensional shapes was better when using the NDGBL approach compared to the conventional instructional method. In particular, the NDGBL group (who learned using 'snake and ladder' board games) showed improvement in their attention, interaction, and performance over the three learning sessions. It is argued that the nature of the game that allowed for students to work in a small group and compete against each other cultivated collaboration and communication through group discussions; for example, to ensure that all group members understood how to use the protractor correctly to measure angles. As far as the Isometric Transformation topic is concerned, several past studies have investigated the learning of the topic using various instructional methods. However, no previous research has focused on NDGBL.

To develop students' understanding of Isometric Transformation, it is suggested that the students are allowed to engage in daily assignments that emphasize the concepts of translation, reflection, and rotation (Panorkou & Maloney, 2015). This practice may be difficult to implement in conventional teacher-centred learning. For example, the study of Akgul (2014) and Guven (2012) found that conventional learning with a paper-pencil environment (copying and writing notes) does not allow students to observe object transformation changes and does not provide meaningful learning experiences to students. Furthermore, conventional learning that emphasizes repetition, practice, and routine methods in achieving learning goals is insufficient to master the concepts in Isometric Transformation. Aktas and Unlu (2017), studied eighth-grade students in Turkey and found that students faced problems in understanding the concepts of translation, reflection, and rotation when using a conventional instructional method. For example, in solving rotation problems, students were observed to have a difficulty in finding the rotation angle and the direction of rotation because they were unable to visually imagine the rotated object. The findings from Aktas and Unlu's study highlighted the need for students to be exposed to physical activities which can provide them a more precise visual picture to help them master the concepts in Isometric Transformation. Furthermore, their study also suggested that an instructional method which uses teaching aids such as physical materials/tools or software was more helpful in attracting students and helping them to achieve the conceptual understanding of Isometric Transformation. Considering the findings of previous studies on the difficulty of have in mastering the topic of Isometric Transformation (Edwards, 2003; Hollebrands, 2003, Luneta, 2015), it is necessary to investigate the effectiveness of NDGBL on the achievement of Isometric Transformation. Furthermore, to date, there are no empirical studies that have reported the effectiveness of NDGBL over a conventional learning method in improving student performance in Isometric Transformation. Consequently, the present study focused on the NDBGL instructional method. It is hypothesized that the use of non-digital games will make students more motivated to learn (Plass et al., 2015) besides increasing interest, creativity and knowledge in mathematics (Nasir et al., 2020).

Learning the concept of Isometric Transformation is essential for students to analyse and synthesise in problem-solving (Mashingaidze, 2012). In Isometric Transformation, lower-level cognitive questions involve determining image coordinates for translation, reflection and rotation. In contrast, higher-level cognitive questions involve determining the centre of a circle and combining two transformations. According to Gulkilik et al. (2015), students could solve problems involving translation using their understanding of the concept of translation through a conventional learning method. However, when more complex reflection and rotation problems are involved, students' ability to apply higher cognitive domains is required. Gulkilik et al.'s (2015) idea is in accordance with the findings from Abdul Wahab et al.'s (2016) study, which found that the level of students' cognitive ability in solving rotation problems is still low. Moreover, a conventional learning method in Isometric Transformation learning that adopted a drill solution by demonstrating methods and algorithms did not improve students' mastery of the topic (Abdullah & Zakaria, 2013). The emphasis on the cognitive levels of questions (lower and higher-level questions) especially in the topic of Isometric Transformation is important in testing students' mastery of the topic. For example, in the context of Malaysian education, Isometric Transformation is one of the mandatory topics tested in secondary schools' public examinations such as the Form Three Assessment and the Malaysian Certificate of Education.

Several past studies have found a significant difference between high-performing and low-performing students in solving mathematics' high-level questions (Abdullah et al., 2019; Tanujaya et al., 2017). It was observed that students who could solve high cognitive level problems were also likely to be able to interpret questions and answer the high-level questions correctly (Abdullah et al., 2019; Tanujaya et al., 2017). Generally, students who can solve the high-level questions of Isometric Transformation are capable of answering the lower-level cognitive questions as well and therefore tend to have better achievements than those who are only able to solve lower-level cognitive questions (Abdullah et al., 2019). For example, in the Isometric Transformation topic, the questions that involved determining coordinates' images after translation or reflection were questions at the level of understanding and application (lower-level cognitive questions), while questions that involved determining the centre and angle of rotation and constructing an image of a transformation were more complicated and involved analysing and evaluating (higher-level cognitive questions) (Xistouri et al., 2014). However, to date, no studies have been conducted to examine the effect of the cognitive level of questions on the students' achievement of Isometric Transformation.

With all the findings documented in past studies looking at the difficulty of learning Isometric Transformation using conventional learning methods and the benefits of the NDGBL instructional method, examining the effect of the NDGBL approach on student achievement is worthy of further exploration. In addition, this study also investigated the effect of the cognitive level of questions on students' performance and the importance of students' ability to perform both lower and higher order thinking to help them answer the questions at different cognitive levels, particularly in Isometric Transformation. Specifically, this study aimed to examine how the NDGBL approach could facilitate the learning of Isometric Transformation in students when compared to a conventional instructional method. In addition, this study sought to determine whether significant differences in students' achievement in the topic of Isometric Transformation existed between the different cognitive levels of questions (high cognitive level intended to explain the impact of the NDGBL approach) and to ensure that readers, especially educators and students, know well which approach can promote a better learning experience. The followings research questions drive the study:

1. Are students' achievements in learning Isometric Transformation different between groups of students using the non-digital game-based learning (NDGBL) method and those using a conventional learning method?
2. What is the students' achievement in Isometric Transformation based on the cognitive levels of the questions?
3. What is the interaction effect between the instructional method (NDGBL vs. conventional) and the cognitive levels of the questions on students' achievement in Isometric Transformation?

2. Methodology

2.1 Research Design

This study used a quasi-experimental design involving two groups of students (control and experimental groups). This study was conducted during school hours using classrooms with existing enrolled students.

2.2 Participants

One hundred and sixteen (116) Form Two (14 years old) students at two national secondary schools in Kuching district, Sarawak, were recruited as participants of this study. Specifically, the participants involved in this study followed the Mathematics learning process in Malay Language. This study did not include those who participated in the Dual Language Programme (DLP) because the percentage of the DLP students was only 15-25% of the overall Form Two students in each school. Homogeneity tests using the latest mathematics examination scores were conducted to ensure that all participants' samples were equivalent in terms of mathematical achievement before the study was conducted. Furthermore, all the participants had not yet learned the topic of Isometric Transformation.

In this study, 58 participants from the first school (School A) became the control group (used the conventional learning method), while 58 participants from the second school (School B) became the experimental group (used the non-digital game-based instructional method, NDGBL). In this way, the interaction between the control and experimental groups was able to be controlled, thus improving the study's validity.

2.3 Materials

This section discusses the materials used in the present study, which were i) Isometric Transformation Achievement Test (used in the test phase), ii) Control group's learning materials (Textbook and Worksheets 1–6—used in the study phase), and iii) Experimental group's learning materials (Transformation Checkers (TC) game and Worksheets 1–6—used in the study phase). Specifically, the control group used examples and descriptions in the textbook, while the experimental group used the TC board as an intervention. In addition, both groups were given the same worksheets (Worksheets 1- 6). All the learning materials used in the present study (both in the study and test phases) were in line with the learning objectives of Isometric Transformation concerning the concepts of translation, reflection and rotation. All materials were evaluated and validated by a panel of experts consisting of four members—a School Improvement Specialist Coaches (SISC+) officer and three Mathematics teachers with more than 15 years of experience teaching Mathematics. During the study phase, the subject teachers for both groups were provided with a daily lesson plan as guidance and reference throughout the learning of Isometric Transformation. This daily lesson plan was designed according to the format and standards set by the Ministry of Education, Malaysia. The daily lesson plan consisted of learning objectives appropriate to participants' ability levels and contained activities to be used during the teaching and learning process. During the test phase, all participants in both groups sat for the Isometric Transformation Achievement Test to assess their current knowledge and understanding of translation, reflection, and rotation concepts. The following is a detailed description of the instruments used in the experiments.

2.3.1 Isometric Transformation Achievement Test (ITAT)

The Isometric Transformation Achievement Test (ITAT) was constructed for the study which included questions from all sub-topics in Isometric Transformation, namely Translation, Reflection and Rotation. Specifically, all the questions in the ITAT were taken from the following sources—textbooks, training modules, Form Three Assessment (PT3) test questions, and Malaysian Certificate of Education (SPM). The questions were also set at various cognitive levels (low cognitive level, 15 marks and high cognitive level, 15 marks). The total marks for the ITAT were 30. Table 1 shows the ITAT specifications used to construct the test questions. The ITAT consisted of two sections: A and B. Section A consisted of ten multiple-choice questions, and section B consisted of six structural questions.

Table 1. Isometric Transformation Achievement Test (ITAT) Specification Table

Section	Cognitive Level	Item Number	Marks
A Multiple Choice Questions	Remembering (lower-level)	1, 2	2
	Understanding (lower-level)	3, 4	2
	Applying (lower-level))	5, 6	2
	Analysing (higher-level)	7, 8	2
	Evaluating (higher-level)	9, 10	2
B Structured Questions	Remembering (lower-level)	11	3
	Understanding (lower-level)	12	2
	Applying (lower-level)	13	4
	Analysing (higher-level)	14	4
	Evaluating (higher-level)	15	4
	Creating (higher-level)	16	3

The questions were appropriate for the participants' level of study, and in line with the standard of the national exams. In particular, for Section A (multiple-choice question), emphasis was given on the lower-level cognitive questions so as to follow the format of the questions for Isometric Transformation in the SPM test paper 1, whereby it only tests the topic of Isometric Transformation at the lower secondary level). The ITAT test questions and format were checked for validity and reliability by experts with a Mathematics background. The time allowed for the participants to answer the ITAT questions was 45 minutes. Analysis on the ITAT in this study showed a Cronbach's Alpha = 0.73, with Difficulty Index = 0.47 and Discrimination Index = 0.52. The range of acceptable item difficulty indices was 0.30 to 0.80, and discrimination indices over 0.40 indicated that the constructed items were appropriate and acceptable (McCowan & McCowan, 1999).

2.3.2 The Learning Materials for the Control Group (Textbook and Worksheet 1-6)

Isometric Transformation was taught conventionally using a mathematics textbook as the main reference material in the control group. Teachers used examples and exercises found in textbooks as learning activities in the classroom. Most of the questions in the textbook are in the form of direct questions that do not include problems that we face in daily life. Thus, these questions often require relatively rigid work steps and limited solution steps. The worksheets (Worksheet 1 to 6) consisted of lower-level cognitive questions and higher order thinking questions to be completed individually or in groups, according to the activity on the daily lesson plan as shown in Table 2. Specifically, worksheets 1 to 6 contained a total of 40 questions regarding translation (Sheets 1 and 2), reflection (Sheets 3 and 4), and rotation (Sheets 5 and 6).

Table 2. Tasks and Cognitive Levels for each Worksheet (Worksheets 1-6)

Worksheet Number	Task	Cognitive Level
1	State, draw and identify image after translation.	Remembering Understanding
2	State the coordinates of the image. Expresses the motion of an object in the form of a translational vector	Applying Analysing
3	Draw the image and the axis of reflection.	Applying
4	Describe the reflection of a pair of points	Analysing Evaluating
5	State the rotation of an image	Applying
6	Determine the coordinates after rotation Draw an image after a combination of two transformations	Analysing Evaluating

2.3.3 Learning Materials for the Experimental group (TC Game and Worksheet 1-6)

The experimental group learned the topic of Isometric Transformation using a board, card and dice game called Transformation Checkers (TC). The TC game was developed for the study, and had the following features:

a) It does not involve high costs,
b) Easily produced by teachers and students,
c) Concise, easy to store and carry,
d) It can be played in a short time and is fun,
e) Able to involve many participants in the gameplay,
f) Has a high competition factor, and
g) Involves the concepts of translation, reflection and rotation.

According to Prastika and Purnama (2013), the game of checkers is both a defensive and an offensive game, like chess. The model took the idea of a traditional checkers game that the researcher wholly modified to fit the learning of Isometric Transformation, and involves translation, reflection and rotation. As shown in Figure 1, the TC game consists of a board, a die, forty pieces of transformation cards, one 'L' ruler and two checkers and can be played in pairs or by up to four people in a group. The participants are provided with a sheet of paper to write the coordinates of movement. The winner of this game is the player who arrives first in the opponent's Victory area. In addition, the winner of each set is rewarded in the form of a badge affixed to the player's clothing. However, if the checkers come out of the restricted area, then the checkers must return to the starting point. The transformation card contains various translation, reflection, and rotation commands randomly distributed in even and odd transformation card boxes. Twenty transformation cards were distributed in each box.

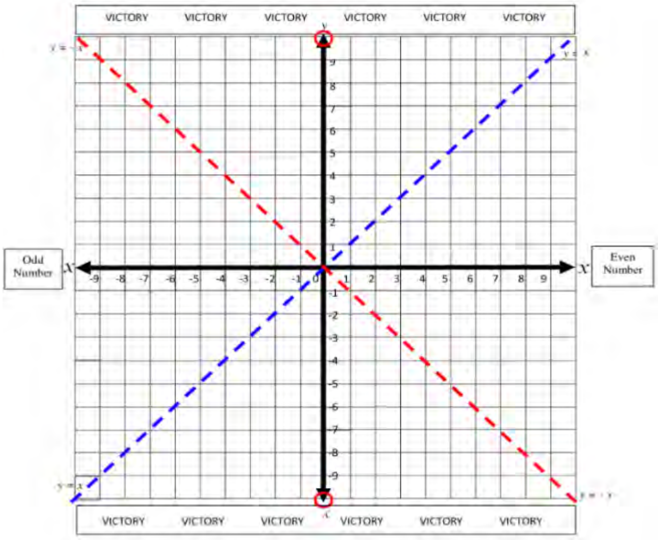


Fig.1 Transformation Checker Board

Transformation cards contain a combination of instructions and questions at varying levels of difficulty to test students' thinking skills. The instructions and questions in this game were more geared towards everyday life situations and required students to interpret and analyse the information before solving a given problem. The difficulty level of the instruction is determined entirely by the content of the card taken. Players can draw two cards at once for higher skill levels and use both commands or select one card only. This is applicable when the player uses their application skills and analyses his checkers' movement to achieve the game's goal. Nevertheless, at the same time, players will not move their checkers as much as they would like as they would be cautious going into the restricted area. For example, after learning the basic translation concepts, teachers could use this game to reinforce participants' understanding of translation concepts using the translation cards. Two participants sit opposite each other, while two more participants sit along the edge of the game board, acting as game referees. The referee ensures that all checkers move according to the instructions on the transformation card. The game begins by rolling the die to determine who should start the game and thus draw a transformation card. The student who gets the highest number starts the game. Then, the player rolls the dice again and draws a transformation card according to the number on the dice. If the number is an even number, the player will draw a card in the even number box and vice versa, if the number is odd. The steps of the game repeat until one of the players successfully reaches the opponent's Victory area. At the end of the first game, the two participants who acted as referees will become players, while the first two players will take positions as referees. The game can last up to several sets according to the time set by the teacher in the teaching plan.

After the game activities in each learning session, the teacher would distribute Worksheets 1-6 to all participants. These worksheets included additional questions that followed the examination format and were arranged according to difficulty levels in line with the skills learned in class to make it easier for teachers to know to what extent the learning objectives have been achieved. The control and experimental groups were given the same worksheets to ensure that only the learning approach differentiated the treatment between the two groups.

2.4 Procedure

Before the study was conducted, applications to conduct the study were obtained in advance from the Ministry of Education Malaysia, the State Education Office and the principals of the schools involved in the study. The selection for the schools involved in the pilot study and the actual study was based on the equivalence of Form Two participants' performance in mathematics obtained from the School Examination Analysis System (SAPS). A briefing session was given to the school principals to describe the study methodology purpose, process, and procedure. In addition, briefing sessions and training were given to the teachers involved in the study to explain the implementation and use of research instruments, such as daily lesson plans and worksheets used in the teaching sessions, as it helps ensure consistency in terms of instructions delivered to the participants. Teachers who taught the experimental group were also given training and guidance on the rules and procedures of Transformation Checker (TC) game, and its use in the classroom. All four mathematics teachers involved in this study have more than 15 years of experience in teaching mathematics.

During the study phase, the control group were taught the concepts of translation, reflection and rotation using a conventional instructional method (discussion of examples in the textbook, drill activities, 'chalk and talk'), while the experimental group used TC games as intervention activities. Unlike conventional learning activities, participants did not have to copy every example and exercise found in the textbook because, through this game, each movement of the checkers represented the solution of the transformation question problem. After the explanation of the theory by the respective class teachers, participants in the conventional group completed the exercises in a textbook or on the whiteboard either individually or in groups, while the experimental group was introduced to the TC game and applied it in the classroom. As the game progressed, participants discussed and exchanged ideas in groups while at the same time competed to win sets in the game. The lesson plan provided for teachers ensured that the independent variables (instructional method) were controlled in each teaching and learning session and were in line with the learning objectives.

The duration of the study was four weeks. Five meetings were arranged, with each meeting taking one hour according to the class schedule of the mathematics subject set by the school. Thus, the implementation period of the study did not take too long to avoid the influence of external factors such as training and additional classes, discussions among peers and teachers, as well as access to other sources of information that can affect the internal validity of the study and achievement (Salleh & Shaari, 2009). Then, in the test phase, both groups were given 45 minutes to complete the Isometric Transformation Achievement Test to test their level of mastery in the concepts of translation, reflection and rotation.

3. Result and Discussion

The data were analysed using a two-way independent ANOVA. Findings showed that the main effect of the instructional method on the achievement of Isometric Transformation of participants was significant, $F(1,114) = 4.421$, $p = .037$. The achievement of the NDGBL group ($M = 14.828$, $SD = 4.160$) for the topic of Isometric Transformation was better than the conventional group ($M = 12.948$, $SD = 5.388$) as shown in Table 3.

Table 3. Mean and Standard Deviation of Isometric Transformation Achievement Test for Both methods.

Group	Mean	Standard Deviation
Control (Conventional)	12.948	5.388
Experiment (NDGBL)	14.828	4.160

The result showed that using the NDGBL approach is perceived to provide higher benefit and effectiveness to participants' performance in the Isometric Transformation topic than using the conventional learning method. In particular, this finding could be due to the nature of the NDGBL, being that it was more fun and engaging, allowing the participants (players) to compete in the game and the challenges it introduced, hence facilitating better learning of Isometric Transformation. Through NDGBL, the participants were more motivated to engage and compete in learning and have the opportunity to try something out of the ordinary in a game context. As documented in past studies, factors such as fun and play experience can maximize participants' engagement in the classroom compared to conventional learning methods (Chen, 2014; Michael & Anugwo, 2016). In addition, NDGBL can create meaningful learning by providing challenges, curiosity, self-expression, discovery, immediate feedback, clear goals, player control, collaboration, competition, rewards and low risk of failure to players (Ke et al., 2015). The seriousness shown by the players in achieving the goals of the game indirectly generates the creativity and critical thinking of the players. While playing, participants who feel they can win will be more likely to continue playing despite increasingly challenging assignments or levels (Palmer, 2016). The participants become more focused and pay full attention while playing because of the game's features that require them to think critically in completing the game tasks. Compared with DGBL and conventional learning methods, the TC game offers participants more opportunities to freely interact, and exchange ideas and opinions directly, as well as allows other participants to help their friends solve a problem. This is because the game rules in NDGBL, as in the TC game, are more transparent than those used in a typical DGBL scenario, thus increasing the element of fun among participants when playing (Berland, 2011). Moreover, the face-to-face interaction between the participants in this NDGBL activity allowed them to better recognize friends' interactions by noting body gestures and facial expressions (Radzi et al., 2017). In this TC game, the two participants who acted as referees could indirectly give immediate feedback if the player made a mistake. For example, when solving a translation problem, a player who mistakenly moved his checkers because the player did not understand the question would be guided by the referee or the opponent. In addition, creativity and problem-solving skills can be nurtured when there are problems and obstacles encountered throughout the game.

Both methods involved the participants in attempting several questions while learning the Isometric Transformation topic. Specifically, the TC game involved the use of the transformation cards whereby the cards provided several instructions and questions that the participants were required to follow and answer respectively, as they played the game. As the questions asked about real-word transformation problems, this indirectly encouraged the higher order thinking skills since the participants had to analyse and synthesise the given problem. Learning the topic of Isometric Transformation via conventional learning also required the participants to answer some questions from the textbook throughout their learning process; however, the questions from the textbook were limited to asking the participants to do direct transformation, hence, exposing them to less opportunity to perform higher order thinking. (Figure 2 shows a comparison of sample questions in a textbook and questions on the transformation cards). It is important to note here that both groups were also asked to complete the same worksheets consisting of several questions, giving both groups the same opportunities for additional exercise.

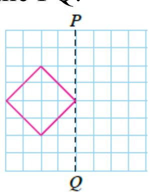
Textbook Questions	**Transformation Card Instructions/Questions**
<u>Translation</u> Object A (-2, 1) undergoes the translation $\begin{pmatrix}3\\2\end{pmatrix}$. Determine the coordinates of object A.	You are looking for your lost pair of shoes. To find the shoe, you must move three steps to the right and then up by two steps.
<u>Reflection</u> Construct an image for the object below under a reflection in the line PQ. 	A mirror is placed parallel to the vertical axis, two steps from your left. Where is the position of your image behind the mirror?
<u>Rotation</u> Determine the coordinates of the image of point A (−3, 2) under a rotation of 90° clockwise at O origin.	Now, it is 6 o'clock. After 15 minutes, the clock shows your new position from the point of origin. Where is your current position?

Fig. 2: Sample questions from a textbook and from instructions on a Transformation Card.

In conventional learning, it was difficult for the participants to imagine the movement of a point undergoing a transformation. Moreover, students were passive and were not required to apply knowledge while solving problems compared to the NDGBL approach, wherein they had to solve challenges using the skills they had learned (Wang & Zheng, 2020). The static object displayed in the figure was not sufficient to aid their understanding of the concepts of translation, reflection and rotation. In Isometric Transformation, participants need to perform their transformation movements visually and physically simultaneously to get a more meaningful learning experience. Exposure to physical and visual activities while playing gave students an advantage in better knowledge retention (Muhamad et al., 2018) than memorising facts and drilling solutions via the conventional learning method. Thus, students' potential can be enhanced through games in education (Hery, 2018). For example, in solving a problem involving "*the rotation of a point at an angle of 90º clockwise at the origin*", participants had difficulty imagining the rotation visually, only on paper, coupled with a grid on the confusing Cartesian plane. However, through the TC game, participants used play tools such as "L" rulers and checkers that could be physically moved and thus, participants could see how the points were rotated. This was intended to provide real and best experience to participants in performing the transformation solution process on the TC board. Several past studies have also reported the effectiveness of the NDGBL method in mathematics learning, such as improved achievement in students' understanding of the concept of polynomial operations (Barros et al., 2019), the concept of algebra (Andini & Yunianta, 2018; Galarza, 2019; Michael & Anugwo, 2016), geometric concepts (Chung et al., 2017; Pratama & Setyaningrum, 2018) and mathematical creativity (Park & Lee, 2017).

The study also revealed that the main effect of different cognitive levels of questions on the achievement of Isometric Transformation is significant, F (1,114) = 140.97, p = <.001. This result suggests that the cognitive level of the question affects participants' achievement regardless of the instructional method used. In this study, the distribution of marks for lower-level cognitive questions and higher-level cognitive questions is the same, and the results show that participants' performance is better for lower-level cognitive questions (M = 8.681, SD = 2.727) than higher-level cognitive questions (M = 5.207, SD = 3.069), as shown in Table 4. The result shows that participants' mastery of higher-level cognitive questions is still at a low level. This finding is in line with the results of a study by Azis (2013), who studied the level of mastery of solving high-level mathematics problems of 100 form four students and found that students' mastery of higher-level cognitive questions was still low.

Table 4. Mean and Standard Deviation of Isometric Transformation Test Scores

		Mean	**Standard Deviation**
Lower-level cognitive questions	Total	8.681	2.727
Higher-level cognitive questions	Total	5.207	3.069

Participants' ability to solve low-level cognitive questions for remembering, understanding and applying was better probably due to several factors. Among them, the lower-level cognitive questions were mainly in Section A (6 multiple choice questions), and Section B (3 structured questions) that tested the levels of remembering, understanding and applying. Participants did not have to show complicated working steps compared to higher-level cognitive questions. Figure 3 shows an example of the lower-level cognitive questions and its solutions.

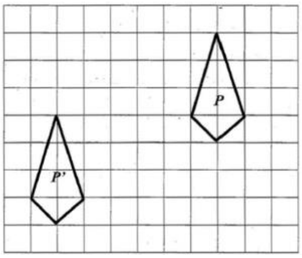
<table>
<tr><th>Question</th><th>Explanation</th></tr>
<tr>
<td>In Diagram 12(a), P' is the image of P under a translation. In the box given, state the translation in the form of $\begin{pmatrix} a \\ b \end{pmatrix}$.


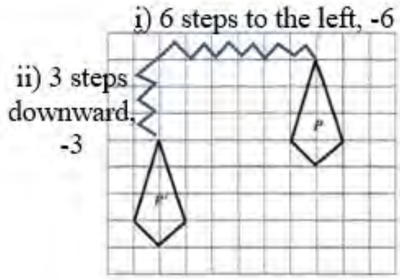
Diagram 12(a)
Answer : $\begin{pmatrix} -6 \\ -3 \end{pmatrix}$.</td>
<td>Based on the participants' understanding of translation, the participant moves a point on the object P to the same point on the image P' starting from the horizontal movement (to the left, -6) followed by the vertical movement (downward, -3).

</td>
</tr>
</table>

Fig. 3. Example of lower-level cognitive question and answer descriptions.

In alignment with findings by Darmawan and Lynch (2018), the probability of students answering lower-level cognitive questions correctly is high. This situation is in contrast with participants' ability to solve higher-level cognitive questions, which required them to translate the skills learned into new situations that involved the ability to think while solving a problem. As shown in the solution of the lower level question problem in Figure 3, it can be concluded that students know that translation is a concept of substitution and does not change the appearance and direction of an object (Aktas & Unlu, 2017). Thus, based on the skill of comparing the appearance of objects, participants were able to answer the question correctly. This situation contrasts with participants' ability to solve higher-level cognitive questions, which required participants to translate the skills learned into new situations that involved the ability to think while solving a problem. In Figure 4, a description of how participants translate the skills acquired during the play experience is applied in solving the higher order question problem.

However, as seen in Table 5, the interaction effect between the cognitive level of the question and the instructional method (NDGBL vs conventional) in the achievement of Isometric Transformation was found to not be significant, $F(1,114) = .070$, $p = .791$, indicating that the interaction of both cognitive level and instructional method did not significantly affect participants' achievement in Isometric Transformation. Nevertheless, mean scores for the lower-level cognitive questions for the experimental group (NDGBL) were slightly higher (M = 9.19, SD = 2.36) than the mean scores for the control group (conventional learning method) (M = 8.17, SD = 2.99). Similar results were also shown for higher-level cognitive questions where the experimental group obtained a higher mean (M = 5.64, SD = 2.81) compared to the control group (M = 4.78, SD = 3.27). This result could be explained by the nature of the instructions and questions asked while learning using the NDGBL method (i.e., the TC game) and conventional learning method. As noted earlier, the transformation cards used the TC game which incorporated several instructions and questions that posed real-world problems, which may have resulted in the participants doing slightly better in answering the higher-level cognitive questions. In contrast, the conventional learning method used the questions in the textbook that asked direct questions, which do not promote higher order thinking as much as in the NDGBL. As for the performance for the lower-level cognitive questions, the increased opportunities the participants had in engaging in higher order thinking while playing the TC game may have given them the additional advantage that resulted in doing slightly better than the conventional group, and this is in line with what has been argued by Abdullah (2019).

<table>
<tr><th>Question</th><th>Explanation</th></tr>
<tr><td>Diagram 15 shows heptagon P'Q'R'S'T'U'V' is the image of heptagon PQRSTUV under a rotation.

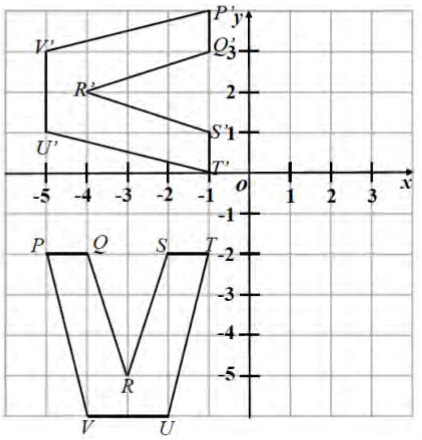


Diagram 15
State:
a) the angle and direction of the rotation.
b) coordinate of the centre of rotation
Answer :
a) Angle of rotation = 90°
Direction = Clockwise
b) (0, -1)</td><td>In this question, participants' analytical and evaluative skills are required in problem solving. Participants need to look at the shape pattern of the object and interpret it to determine the direction of rotation. In conventional learning, it may be difficult for participants to imagine how rotation is performed; however, based on participants' experience of playing NDGBL or TC games in this study, and participants can determine the rotation and angle of rotation using the 'L' ruler in the game. Using a regular ruler instead of an 'L' ruler during the test, participants applied an 'L' ruler through a regular ruler to obtain angles and points of rotation.

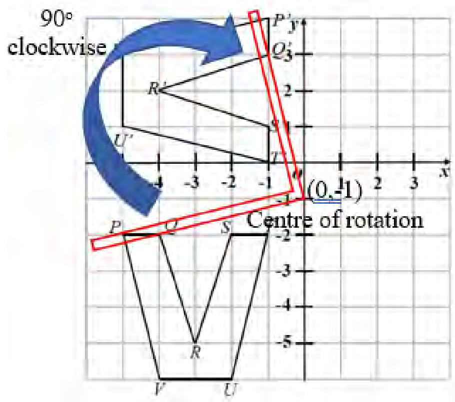

</td></tr>
</table>

Fig. 4. Example of higher-level cognitive question and answer descriptions.

Table 5. Mean and Standard Deviation of Instructional method and Cognitive Level of Questions.

	Approach	Mean	Standard Deviation
Lower-level cognitive questions	Conventional	8.172	2.986
	NDGBL	9.190	2.358
Higher-level cognitive questions	Conventional	4.776	3.272
	NDGBL	5.638	2.814

4. Conclusion

In the context of the instructional method, the findings of present study highlight the role of NDGBL in enhancing participants' learning of the Isometric Transformation topic. In particular, this study used the Transformation Checkers (TC) game that involved cards, board games, dice and other concrete materials which allowed for more engaging, fun, interactive and meaningful learning to occur in the NDGBL group, resulting in better performance for that group than the conventional group. Therefore, in terms of practical implications in schools, based on these findings, it is recommended that teachers should consider NDGBL in the teaching and learning process, especially in improving the understanding of Isometric Transformation in mathematics, which has been reported in previous studies as difficult (Fife et al., 2019; Luneta, 2015).

As mentioned earlier, there is no empirical evidence from previous studies regarding the effectiveness of the NDGBL approach in the learning of Isometric Transformations (translation, reflection and rotation) in mathematics. However, the challenge of mathematics learning that is generally considered tedious and complicated may be overcome by using the NDGBL approach because the NDGBL features encourage exploration, student engagement, and student motivation to learn. This study also proves the effectiveness of the cognitive level of questions on students' mathematical achievement. The breakdown of lower-level cognitive questions and higher-level cognitive questions scores in the study allows the researcher to identify students' level of cognitive ability in solving the questions according to the set cognitive level. According to the item specification table levels, these findings allow teachers to formulate question breakdown ratios to measure student achievement.

One limitation of the present study would be the sample used; the participants were from two local daily schools, that used the Malay Language medium to learn mathematics. Therefore, it is recommended that further inquiry would involve a sample of Form Two students who follow the DLP (Dual-Language Program); learning mathematics and science in English as well as a sample of students from fully residential schools to determine if the same patterns of findings could be observed despite the differences in students' academic background and the language medium used in the teaching and learning process. In addition, the roles of NDGBL could also be further examined in learning Isometric Transformation at other levels of studies, and in other subjects.

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