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).