The Impact of Digital Game-Based Learning (DGBL) Employing Permutations and Combinations Game (PnC Game) on Foundation Students

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Abstract
This study utilised digital game-based learning (DGBL), which merges applied computing with education through the creation of the Permutations and Combinations Game (PnC Game). Permutations and combinations topic was chosen because students frequently struggle to solve problems connected to the topic, particularly in recognising permutations or combinations situations. Students also struggle to put theory into practice (CLO3). Therefore, the PnC Game was built to help students learn the topic at their own pace. By engaging in the game, students able to solidify their theories indirectly. This study involves 27 foundation students from A-Level at INTEC Education College (INTEC) and 22 from the STEM Foundation Center at Universiti Malaysia Terengganu (UMT). They were given a Pre-Test set before playing the game and a set of Post-Test after playing the game. The majority of students performed better on the Post-Test despite the fact that the topic of permutations and combinations was already covered in high school, according to the data that was gathered and analysed from both tests. The paired t-test result reveals a statistically significant improvement in performance after learning with PnC Game. On the other hand, regardless of their Additional Mathematics performance in the Malaysian Certificate of Education (SPM), our study showed that learning via the PnC Game has improved students' grasp of permutations and combinations topics.

Keywords: Digital game-based learning, Permutations and combinations, Learning performance, STEM education

Introduction
Games' appeal to children and adults, particularly the Net generation, is apparent. As a result, numerous academic disciplines and industry games are rapidly evolving and highly demanding as educational vehicles. However, not all games are helpful and successful for learning; only well-designed games are (Shute & Ke, 2012). For instance, in the 1980s, players of the Mario Brothers game had fun, felt emotions, were aware of their potential, established constructive communication and relationship, and solved problems (Karakoç *et al*., 2020). This contrasts with educational games, which are synonymous with the terminology such as computer games, video games, serious games, game-based learning, and instructional games (De Freitas, 2006), and are primarily for educational learning purposes which offer

knowledge acquisition and behavior change.

DGBL uses the digital game for educational purposes and plays a significant role in teaching material that is not innately engaging to anyone but needs to be learned by using games for review and reinforcement (Prensky, 2001). According to Snow (2016), DGBL promotes participants to take on active roles, solve problems, build, and use active learning skills. This is supported by Hwa (2018) that DGBL is more effective than traditional classroom-based learning. However, this type of active learning is absent in most circumstances in a regular classroom setting. Consequently, students, particularly in mathematics, lack problem-solving skills.

According to Hussein *et al*. (2021), the DGBL technique enables students to study at their own pace and go over the course material at their convenience. This is crucial for their knowledge and motivation of these permutations and combinations topic. Numerous studies have been conducted in a variety of subject disciplines to describe the effects of DGBL in promoting motivation, engagement, enjoyment (Gee, 2003; Bakar & Ayub, 2020; Troussas *et al*., 2020), and enthusiasm (Sun *et al*., 2021).

Therefore, in this study, PnC Game was designed by a team of lecturers from INTEC Education College (INTEC) and STEM Foundation Center, Universiti Malaysia Terengganu (UMT), to align the DGBL technique. It covers topic permutations and combinations. This topic was chosen as the students have difficulties comprehending and applying traditional teaching and learning. Students can use this game with various educational backgrounds, including SPM, foundation, degree, or similar. Three different difficulty levels have been set for the students to play the game. This adapts to each learner's prior knowledge, skills, and pace.

The PnC game design enhancements include the voice-over, audio, animation, abstract design, mobile-friendly, and post-assessment revision to create a fun and interactive learning environment. The game design patterns and 'game feel' can motivate continued behavior and engagement (Lewis *et al*., 2012; Swink, 2008). Hence, it would be better and easier to understand in a game environment as the computer-based maths game has significantly increased the knowledge level and students' performance (Muntean *et al*., 2018).

Smartphones, tablets, and iPads are electronic devices used to play digital games. Therefore, DGBL, which integrates digital tools with game-based learning, is one approach to enhancing learning effectiveness. According to Khenissi *et al*. (2013), learners' desire to learn is improved when using the learning version of existing computer games, making learning more enjoyable. Besides, the electronic devices used to play the PnC Game are user-friendly and mobile. This allows learners to access the game anywhere and at any time. According to Skiada *et al*. (2014), mobile apps can reduce student uncertainty and improve concept transfer. Mobile apps positively impact students' attitudes toward learning activities (Fabian, 2019; Supandi *et al*. 2018; Huet & Tcheng, 2010). Students may be more focused, organized, and efficient in their learning activities when using these mobile apps (Kay & Lauricella, 2011). Furthermore, this study occurs during the Covid-19 pandemic, necessitating a new approach to teaching and learning.

The graphic design for this PnC Game was abstract, with two-dimensional design and simple art components. Learners like the abstract style over the realistic style, and the design is better adapted to offer more influences in the gaming context (Lee *et al*., 2018). This abstract design includes solid colours, constructed textures, and minimal forms. Furthermore, it encourages a minimalist aesthetic by limiting realistic techniques like drop shadows, bevels, emboss, and gradients (Oswald & Kolb, 2014).

There are a few approaches used in this game. Firstly, the differentiated approach and secondly, the constructive approach. For the differentiated approach, students were guided through voice-over instructions. Liao *et al*. (2019) stated that the voice-over instructions established the essential knowledge to help the students free up time for strategic gameplay and engage in goal-oriented action planning while playing the game in the context of a collaborative DGBL. The voice-over, an audio system, storytelling approaches, and cognitive recognition tools help deliver the content (Khalip *et al*., 2018). According to Byun & Loh (2015), voice-over game-based learning is more engaging than non-voice-over game-based learning. A study by Hébert *et al.* (2021) validated that the teacher's voice-over was beneficial but not hindered when applying DGBL.

Meanwhile, the constructive approach that has been used in this game highlights students through self-directed exploration, reflection, and evaluation (Kapur, 2020). Therefore, the DGBL method via PnC Game aims to help students learn permutations and combinations at their own pace as they frequently struggle to solve problems connected to the topic. According to Pannese and Carlesi (2007) and Vanduhe *et al.* (2000), participants benefited from a feeling of agency and control over the pace and duration of learning while adopting DGBL. By engaging in the game, students may be able to solidify their theories indirectly, resulting in enhanced student performance. Thus, this PnC Game was created with some game design enhancements to assist students in recognising and solving difficulties related to the topic using DGBL, which significantly improves performance through interactive engagement (Hung *et al*., 2014; Perera *et al*., 2017).

Methodology

This study used a cluster sampling method to select samples. For INTEC, the students have been divided into 5 clusters based on the number of classes. The STEM Foundation Center population was divided into 3 clusters based on the number of classes. Two clusters from INTEC and one cluster from STEM Foundation Center were randomly selected as the samples. The samples included a total of 49 students, where 27 students were from INTEC, and another 22 were from the first-semester foundation students from STEM Foundation Center.

Pre-Test (1 hour)

3 level difficulty (Easy, Medium & Hard)

↓

Learning PnC Game consists of permutations and combinations
(Self-paced in one week)

↓

Post-Test (1 hour)

3 level difficulty (Easy, Medium & Hard)

Figure 1: PnC Game Study Flow

Figure 1 depicts the flow of the PnC Game study. In conducting the Pre-Test, students were given an hour to complete a set of questions regarding permutations and combinations. This was to test their knowledge about this topic before playing the PnC Game. The number of correct answers in the Pre-Test was summed up as their Pre-Test score. The snapshot of Pre-Test questions is shown in Figure 2. Since the study was conducted during the pandemic, the Pre-Test was set using Google Forms, and the students were monitored using the ZOOM platform. They were then provided a link to the PnC Game to self-explore the game within one week.

Figure 2: Snapshot of Pre-tests PnC Game

The PnC Game was divided into two parts which are learning and exercises. The students were guided through the learning process by the instructor's voice-over. In parallel with the instructor's voice-over, the students were also directed to undertake some activities such as drag and drop or enter the correct answer to finish the given example. Figure 3 shows the snapshot of the Learning part of the PnC Game.

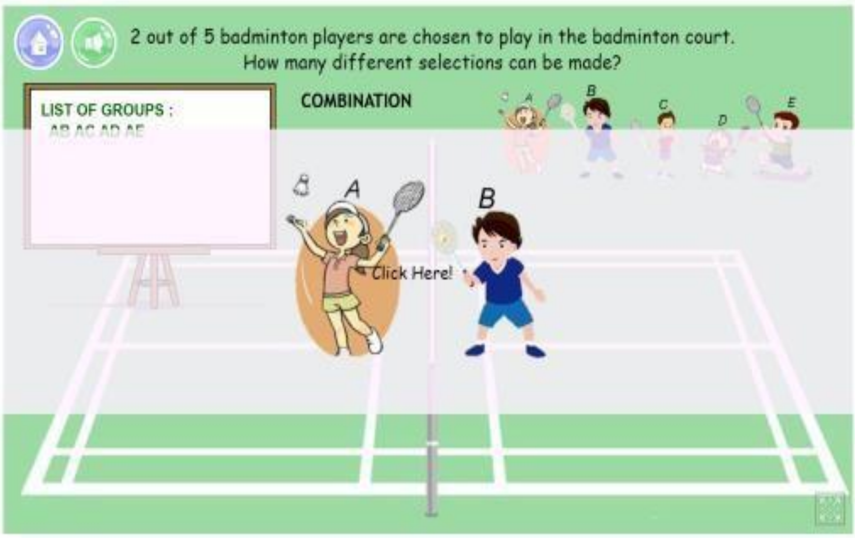

Figure 3: Snapshot of Learning Part from PnC Game

Exercise is the Post-Test phase, where students must answer all the PnC Game's exercise questions. The exercises include an exciting feature where the questions are based on the Covid-19 pandemic situation, giving students a taste of how permutations and combinations are used in real life. Students who are uninterested in learning mathematics cannot perceive how mathematical ideas may be applied in everyday life (Hwa, 2018), so they were given real-life problems in this PnC Game. Figure 4 shows the snapshot of the Exercise part in the PnC Game.

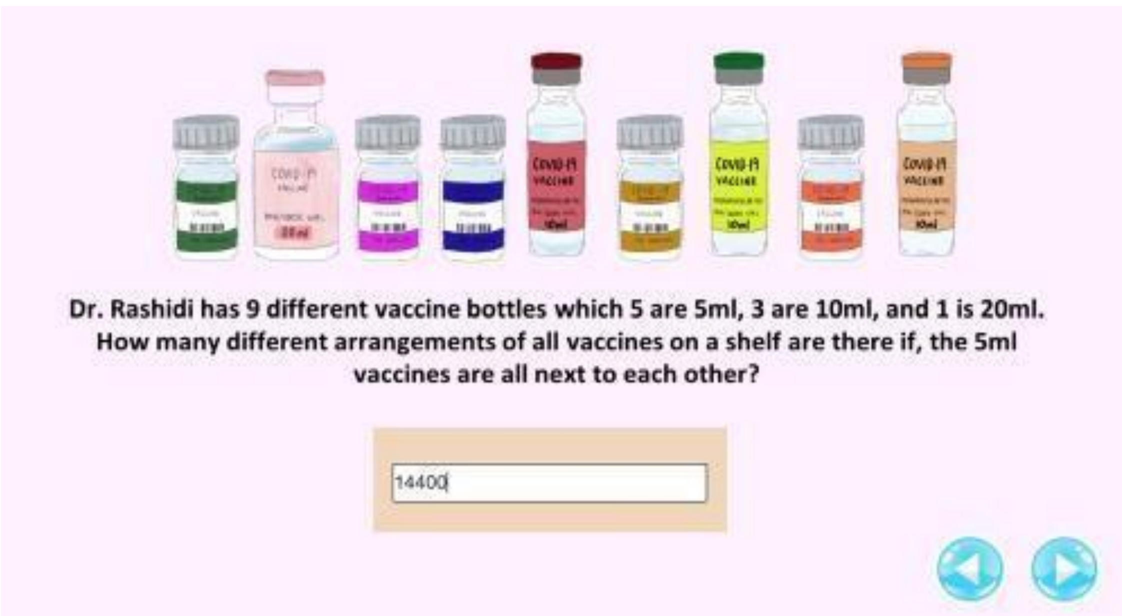

Figure 4: Snapshot of Exercise Part from PnC Game

After answering all the exercises' questions, students can examine their scores and select the revision button for incorrect questions. Students can indirectly revise their learning sessions on their own. Students were also observed via the ZOOM platform during Post-Test. The questions for both the Pre- and Post-Test were arranged into three degrees of difficulty: easy, medium, and hard. The degrees of difficulty were designed so that students must examine and use critical thinking to come up with the necessary solutions. The students' scores were recorded in a spreadsheet and then will be imported into SPSS Statistics software to be analysed.

Descriptive analysis was done to overview the students' demographic profiles. The Pre-Test and Post-Test scores for each student were compared to see if there had been any improvement in their understanding of permutations and combinations after playing the PnC Game. To see the differences between Pre-Test and Post-Test scores, paired sample t-test analysis with 0.05 level of significance was used. Paired sample t-test was used because the two samples (Pre-Test and Post-Test) that need to be compared are dependent (Bluman, 2018). Thus, the changes between the two mean can be seen by subtracting the Pre-Test and Post-Test scores= Pre-Test - Post-Test). The hypothesis for this paired sample t-test is $H_0: \mu_D = 0$ and $H_0: \mu_D \neq 0$. The hypothesis indicates that if there are no changes in the mean marks for both tests, H_0 needs to be accepted. A 95% confidence interval was used to see the location of the difference between the mean of Pre-Test and Post-Test scores. The analysis of the results was then explored in greater depth in the next section.

Results and Discussion

The students were from two different institutions; 27 were from INTEC, and 22 were from the STEM Foundation Center. Students must get at least a C+ in SPM Additional Mathematics to enrol in INTEC and the STEM Foundation Center. Furthermore, 97% of students from INTEC are Public Service Department (JPA) scholars doing an A-Level programme. There are 24 female respondents (49%) and 25 male respondents (51%). Only 2.04 percent of students who took Additional Mathematics for their SPM received a C, whereas the majority (57.14%) received an A.

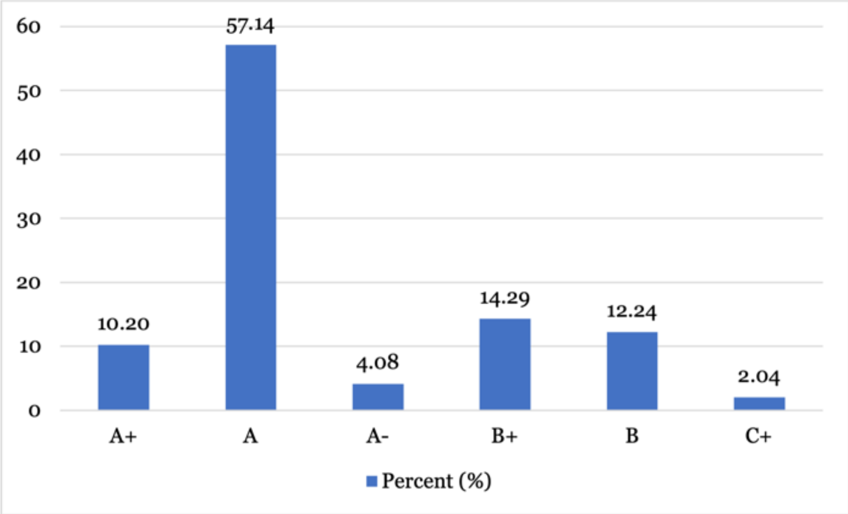

Figure 5: Additional Mathematics Grades in SPM 2019 and SPM 2020

Each test has three difficulty levels, each containing five questions. Table 1 presents the comparison value for mean and standard deviation for both Pre-Test and Post-Test.

Table 1: Pre-Test and Post-Test Value

Level	Test	Mean	SD
Easy	Pre-Test	2.14	1.155
	Post-Test	3.45	1.119
Medium	Pre-Test	0.76	0.99
	Post-Test	2.2	1.369
Hard	Pre-Test	1.24	1.164
	Post-Test	2.47	1.672

For comparison, the average score for Post-Test is better than Pre-Test. Referring to Table 1, the highest difference is obtained at the medium level with a 1.44 score. To identify significant improvement after learning using a PnC Game, paired t-tests were conducted for each test level and the overall score for Pre-Test and Post-Test. The paired t-test was conducted by Pre-Test score – Post-Test score. Negative values obtained for the mean explain that Pre-Test marks are lower than Post-Test marks.

Table 2 shows that each pair resulted in a negative value in mean where for easy level, -1.306, medium level -1.449 and hard level -1.224. The table also shows that the respondents do have a significant improvement after learning using a PnC Game for each level based on the p-value = 0.000 for all levels where it is smaller than 0.05 significant level. The confidence interval also shows a negative value which did not contain 0. If the confidence interval has a 0 value, the difference between the two scores is insignificant (Bluman, 2018).

Table 2: Paired Sample t-test by Different Levels of Difficulty

Pre-Test – Post-Test	Easy	Medium	Hard
Mean	-1.306	-1.449	-1.224
t	-5.871	-6.466	-5.158
p-value	0.000	0.000	0.000
95% C.I. (Lower)	-1.753	-1.900	-1.702
95% C.I. (Upper)	-0.859	-0.998	-0.747

Meanwhile, in Table 3, the average score for the Pre-Test is 4.14, while the Post-test score is 8.12 on average. It shows that there is score improvement after learning using PnC Game.

Table 3: Pre-Test and Post-Test Score

Test	Mean	Median	SD
Pre-Test Score	4.14	3	2.723
Post-test score	8.12	8	3.539

To see the significant improvement in the overall test, another paired t-test was conducted. Table 4 shows that there is significant improvement after learning using PnC Game using 0.01 significant level (p-value = 0.000, df=48) with t = -7.259.

Table 4: Paired Sample t-test

Test	t	df	p-value
Pre-Test – Post-Test	-7.259	48	0.0000

Even though the students have already learned permutations and combinations during their SPM under the Additional Mathematics subject, their Pre-Test scores showed that they could not recall the topic clearly. Based on the analysis, this study proved that learning using PnC Game could improve their understanding of the permutations and combinations.

Due to the constraints of the standard classroom-based learning technique, this study looked into the possibility of incorporating a DGBL approach into the statistics area, specially permutations and combinations. According to the findings, the DGBL method appears to be more effective in assisting students' understanding than traditional teaching methods. Students could strengthen their knowledge and concepts in an indirect approach, resulting in enhanced student performance. DGBL is perfect for bringing a creative element to a bland classroom setting.

Conclusion

In this study, the use of multimedia components voice-over, audio game, animation, abstract design, mobile-friendly, and post-assessment modification in the design and development of the DGBL environment played a significant part in how the DGBL approach benefits students.

The paired t-test shows a statistically significant improvement in student performance after learning with the PnC Game. However, various enhancements to the PnC Game can be implemented in the future. The current PnC Game was designed to meet the needs of each individual. As a result, it is recommended that the games be more interesting and helpful if they were designed for students to study mathematics together or competitively, as stated by Hung et al., 2014. Furthermore, while the PnC Game was designed to improve student performance, feedback from students who have used it is essential because it can demonstrate how mathematical learning in a game-based learning environment can boost student satisfaction and engagement.

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