The Usage of Game-Based Learning Approach in Physics Education: A Novel Board Game in Learning Resolution of Forces among Upper Secondary

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Abstract

Game-based learning (GBL) is an innovative teaching pedagogy that uses games to promote learning or act as educational tools. The teaching and learning of Newton's laws of motion, especially the topic of Resolution of Forces, are challenging when students cannot understand abstract concepts, leading to the failure to solve related problems. This study introduces a novel board game called Catch the Flight, designed to facilitate students' learning of resolution of forces and enhance their problem-solving skills. The board game was systematically designed based on the ADDIE model and the Integrated Design Framework of Playful Learning. A case study was conducted to test and evaluate the board game quality involving 41 upper secondary school physics students in the state of Perak, Malaysia through MEEGA + KIDS self-assessment questionnaire. The results suggest that the game can offer students a positive player experience and, at the same time, enhance students' learning and motivation. Based on the findings, it shows that the game is fun, user-friendly, relevant, and promotes social interaction. This study offers valuable insights for educators considering using educational board games as an instructional strategy or those interested in developing new educational games to teach physics.

Keywords: Board game, game-based learning, Newton’s laws of motion, resolution of forces.


Introduction

Newton's laws of motion are a central topic of introductory physics courses that require students to understand the concept of forces. However, Malaysian upper secondary school students encounter challenges in comprehending and gaining
proficiency in the forces and motion concepts, primarily because these concepts tend to be abstract (Badruldin & Alias, 2022; Ibrahim et al., 2019). Hence, they face difficulties in solving related problems, especially when students must break down the forces acting on an object into the x and y-components and calculate the object's acceleration. Thus, to facilitate students' learning for resolution of forces, especially in solving physics problems and address students' low motivation in learning physics, a novel educational board game named "Catch the Flight Board Game" was developed in this study.

Play and games have historically been closely associated with education. Games have been used for educational purposes in formal settings since the 1960s (Ifenthaler et al., 2012; Moncada & Moncada, 2014). According to Pinedo et al. (2022), game-based learning (GBL) involves using games to facilitate learning within an educational environment or as instructional aids. Even though we are in an age characterised by rapid digital advancement, incorporating games into the classrooms is not restricted to digital games.

Non-digital games, such as board games, could offer numerous advantages. Board games could enhance learning efficiency, improve engagement and motivation, and decrease the time spent on teaching and the instructors' workload. (Gresse von Wangenheim et al., 2019). Moreover, board games offer a more cost-effective option, encourage social interaction, and ensure equitable participation through a turn-based structure, where each player is granted an equal opportunity to engage in the game (Poole et al., 2019). Besides, institutions lacking fundamental technology infrastructure could also employ board games to carry out the GBL approach.

Additionally, educational board games have proven highly effective for teaching, outreach, and increasing awareness in STEM disciplines (Chiarello & Castellano, 2017). Board games have also been effectively employed in different fields as an instructional tool that fosters learning, such as management courses (Nordin & Omar, 2022), marine science (Lin et al., 2019), complex scientific concepts (Chiarello, 2015), mathematics (Hawes et al., 2020), chemistry (Tsai et al., 2020), language (Poole et al., 2019), and computational thinking (Kuo & Hsu, 2020).

This can be attributed to several factors where board games create an immersive and captivating atmosphere, provide the opportunity to interact with abstract concepts through visuals and metaphors, and encourage discussion (Bodnar & Clark, 2017; Chiarello & Castellano, 2017). Therefore, educational board games are believed to be a productive and streamlined teaching and learning approach.

This case study aims to evaluate the quality of the novel Catch the Flight board game. According to Battistella et al. (2017), a high-quality educational game has clear goals and could offer students an engaging, enjoyable and stimulating environment to foster learning and keep students motivated. Hence, Catch the Flight board game is assessed from three quality factors: usability of the game, player experience and the impact on learning the topic of Resolution of Forces.

The following analysis questions are formulated based on the research objectives:

I. Is the board game attractive and user-friendly?

II. Does the board game offer students a positive player experience?

III. Does the board game foster students' learning in solving problems related to the resolution of forces?
It is hypothesised that implementing the Catch the Flight board game will improve students’ performance in the post-test compared to the pre-test and contribute to a positive player experience among the students.

**Literature Review**

**MEEGA + KIDS Model**

The MEEGA + KIDS model was introduced by Christiane Gresse von Wangenheim et al. (2018), a tailored version of the widely utilised MEEGA+ model (Petri et al., 2018) for evaluating educational games. According to Calderón and Ruiz (2015), it is considered one of the most prevalent models for assessing educational games. MEEGA + offers structured support for appraising how players perceive educational games and how they are effective for their learning. The development of the MEEGA + model involved a systematic approach, breaking down evaluation objects into specific metrics and establishing a standardised measurement tool in the form of a self-assessment questionnaire.

![Figure 1. The MEEGA + KIDS model](source)

Figure 1 shows the compositions of the MEEGA + KIDS model. The quality of an educational game can be determined via three quality factors: player experience, usability and learning. Player experience is a quality aspect that encompasses the student’s profound engagement in the gaming activity, encompassing their perception
of learning, emotions, enjoyment, and interactions with the game, surroundings, and other players. Meanwhile, usability is the extent to which the students can effectively and efficiently utilise an educational game to accomplish predetermined learning objectives of a subject. It encompasses four dimensions, including learnability, operability, aesthetics and accessibility. The evaluation of the learning quality is based on Bloom's taxonomy levels, which contain remembering, understanding, and applying.

The ADDIE Model

The ADDIE model is a framework that serves as a commonly utilised model for creating instructional materials and training programs across diverse domains (Bamrara & Chauhan, 2018). The acronym ADDIE represents the stages of Analysing, Designing, Developing, Implementing, and Evaluating.

The ADDIE model is a systematic and organised process, commencing with the analysis stage to ascertain user requirements. Subsequently, it progresses to the design phase, where objectives, instructional strategies, and content are determined. The development stage involves the actual creation of materials. Finally, the last phase entails the implementation and evaluation of the products.

The ADDIE model is incorporated into the research framework of this study to guide the design and development of the educational board game because its steps utilise an input, processing, and output structure, simplifying the instructional design process and enhancing its accessibility for designers.

The Integrated Design Framework of Playful Learning

![Integrated Design Framework of Playful Learning](source)

Figure 2. Integrated Design Framework of Playful Learning

Source: Plass et al., 2014
Plass et al. (2014) proposed a framework known as the Integrated Design Framework of Playful Learning that offers educators a set of principles that show the possibilities of educational games and guide educators in designing educational games. The framework is shown in Figure 2.

When designing educational games, it is crucial to include the three vital elements - affect, cognition, and social or cultural to ensure that students stay actively involved with the intended educational goals throughout their gaming experience. Besides, all the learning game design elements should be considered to be included in the design of the educational games. Furthermore, the designers must consider the four types of engagement: affective, physical, cognitive and social or cultural to provide students with a playful learning environment.

We employed this framework as the core in designing and developing the educational game in this study because it helps us to ensure that the board game created is engaging and conducive in achieving the desired learning outcomes since it integrates the three key elements in the game design process.

Materials and Methods

Research Design

This study employed an exploratory research approach by performing a case study to understand and observe the usage of educational board games in fostering the learning of resolution of forces among upper secondary school physics students. Figure 3 shows the research framework of this case study that follows the procedure outlined by Wohlin et al. (2012) and Yin (2017). Meanwhile, the development of the board game was based on the instructional design model ADDIE (Branch, 2009) and the Integrated Design Framework of Playful Learning (Plass et al., 2014).

![Figure 3. The Research Framework.](image)

Research Procedure

1. Study Context
Catch the Flight board game was developed to enhance upper secondary school physics students’ learning on resolution of forces through a low-cost non-digital GBL approach. In order to understand the board game’s quality, a case study was conducted to evaluate the game systematically through the MEEGA+ KIDS model proposed by Gresse von Wangenheim et al. (2019).

In the context of this study, the quality of the board game is defined according to the following factors: (i) usability of the game, (ii) player experience, and (iii) learning. The usability of an educational game encompasses four dimensions: learnability, operability, aesthetics and accessibility (Gresse von Wangenheim et al., 2019). Usability is the extent to which students can use the educational game to effectively and efficiently achieve their learning goals. In this study, the usability of the board game is defined as how well the students can use it to facilitate their learning in solving problems related to resolution of forces.

Meanwhile, the player experience is the player’s overall experience and engagement. In this case, it refers to students’ experience while interacting with the board game. The quality of their experience includes how they view their learning progress, emotional reactions, enjoyment level, engagement with the game and its surroundings, and interactions with their peers (Wiebe et al., 2014; Gresse von Wangenheim et al., 2019).

The quality of the learning aspect is evaluated through students’ problem-solving skills performed via the post-test consisting of real-world problems related to resolution of forces.

2. Development of the Board Game

Catch the Flight board game was developed based on the Integrated Design Framework of Playful Learning (Plass et al., 2014), shown in Figure 2, by following the steps in the ADDIE instructional design model (Branch, 2009). During the analysis phase, students’ difficulties in learning the topic of Forces and Motion, their needs, and their learning environment were examined. Based on the analysis, the researchers decided to design the game as a board game. Then, the learning objectives and specific learning outcomes were outlined based on the physics syllabus to create the game. During the design phase, the three major aspects in the Integrated Design Framework of Playful Learning: cognitive, affective and socio-cultural were taken into account. The four types of engagement (affective, physical, cognitive and social engagement) were included in the game design to offer students a playful learning environment. Multiple trial game sessions were conducted throughout the development phase to assess the game rules and mechanics and to fine-tune the game’s duration to suit the weekly period students learn physics in school.

3. Implementation and Evaluation of the Board Game

The board game was implemented in a "Physics Excellence Enhancement Program" in a secondary school in Perak, involving 41 upper-secondary physics students for two weeks. The program consisted of two workshops that were conducted weekly for three hours. An evaluation was conducted via a case study with a pre-test and post-test design to investigate whether the board game helps students learn resolution of forces and assess their experience playing the game and its usability. A case study was employed because it enables in-depth exploration of an individual, a group, or an event (Wohlin et al., 2012; Yin, 2017). In this study, the procedure of conducting the case study was defined, planned and executed based on the steps outlined by Wohlin et al. (2012) and Yin (2017).
The case study started with implementing the educational board game (treatment) during physics lessons. Before the implementation, students answered a pre-test consisting of 10 real-life problems related to resolution of forces. After the treatment, students answered the post-test and the MEEGA + KIDS self-assessment questionnaire to evaluate the quality of the board game.

4. Data Analysis and Interpretation

The descriptive statistic method was used to analyse the data collected through the MEEGA + KIDS self-assessment questionnaire to assess the usability and player experience of the board game as perceived by the upper secondary school physics students. The descriptive data were analysed based on the mean interpretation value proposed by Nunnally and Bernstein (1994).

Additionally, a one-sample t-test was employed to compare the pre-test and post-test results after implementing the board game. Descriptive data analysis was conducted using SPSS software version 21.0.

Population and Sampling

Since this study aims to evaluate the quality of the board game designed to enhance students' learning of resolution of forces through students' perceptions, a purposive sampling method was used. There were a total of 65 upper secondary school students who took physics subject in the school. Out of 65 students, 41 were identified as facing difficulties in solving problems related to resolution of forces. Hence, the 41 students were selected to participate in the "Physics Excellence Enhancement Program". They consist of 18 male students and 23 female students. Their participation was voluntary, and informed consent was collected.

Research Instrument

In this study, the MEEGA + KIDS self-assessment questionnaire introduced by Gresse von Wangenheim et al. (2018) was adopted to evaluate the quality of the board game. There are 25 items in total, which are on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) to collect students' perceptions towards the usability of the board game (7 items) and students' experience as players (17 items). This instrument has a Cronbach's alpha value of 0.882 (Gresse von Wangenheim et al., 2020).

According to Gliem and Gliem (2003), when Cronbach's alpha approaches a value of 1.00, it indicates a strong degree of interconnectedness among the items, suggesting that they effectively assess the same fundamental construct. Hence, the instrument used in this study has high reliability.

Meanwhile, the Spearman correlation coefficients between items were used to determine the instrument's validity. Gresse von Wangenheim et al. (2020) found that the items designed to measure different quality factors do not strongly correlate (discriminant validity). Hence, the items are distinct and measure different aspects or qualities of educational games.

Concurrently, a pre-test and post-test consisting of 10 real-life problems (questions adapted from the past years' examination questions) related to resolution of forces were employed to measure the learning aspect.
Catch the Flight Board Game

Following the steps in the ADDIE model and the elements of the Integrated Design Framework of Playful Learning, the researchers designed and developed a board game named Catch the Flight as an innovative approach to teach the topic of Resolution of Forces using low-cost non-digital GBL.

1. Context Analysis

The target users of this board game are upper secondary school students aged between 16 and 18 year old who are taking physics as one of their pure science subjects. Students have some prior knowledge regarding Newton's laws of motion, but they face challenges while solving problems related to resolution of forces. Students are used to playing digital games at home, yet they are interested in playing non-digital games, such as board games and card games. Students in Malaysia learn physics face-to-face in schools for 2 hours and 30 minutes on average weekly. Lessons are conducted either in the classrooms or in physics laboratories.

Based on the standard curriculum of secondary school physics in Malaysia, classical mechanics is the first topic students learn, and it consists of the concepts of forces and motion, which comprise Newton's laws of motion. The Resolution of Forces is a subtopic of Newtonian mechanics. After learning this subtopic, students must be able to resolve a force acting on a rigid body into two components when the object is pulled or pushed at an inclined angle or slides on an inclined plane due to its weight.

2. Design and Development of the Board Game

The development of this game is specifically intended for use within a classroom setting that focuses on enhancing students' learning on resolution of forces. Its primary objective is to solidify comprehension of the concepts of resolution of forces. After playing the game, students will be able to resolve forces into x and y components, solve real-life problems related to resolution of forces, and calculate the resultant force acting on the object.

The researchers opted for a non-digital GBL approach to offer students a more engaging and productive learning experience. Additionally, the tangible components in the board game allow students to physically interact with the game, move pieces, and make decisions based on their observations and the position of these pieces. Due to practical constraints, the game's duration is 10 to 20 minutes, and it has been designed as a board game suitable for groups of 2 to 8 players.

Figure 4 shows the board game cover, illustrating the game's main characters: Priya and her family rushing to catch their flight. The game's narrative is that players need to assist Priya and her family in quickly reaching the boarding room to catch their flight for their vacation. This is achieved by strategically positioning tiles to create a path to the boarding room while overcoming obstacles encountered during their journey. Students are required to apply their understanding of force resolution and resultant forces to address the challenges presented in the game.
Meanwhile, Figure 5 illustrates the game contents of the board game: a physical game board, 24 tiles, 24 task cards, a gadget, one die, and 16 heart tokens. The physical gadget shown in Figure 5 helps the students to visualise the components of forces acting on an object and resolve the forces into x-component and y-component.

This game's social interaction mode blends elements of cooperation and competition. Students have the flexibility to participate individually or in pairs. When teamed up, students can work together to tackle problems while simultaneously vying against other game pairs. This design aims to sustain students' interest in understanding force resolution and resultant forces by actively involving them in problem-solving and enhancing their motivation.
Every Task Card presents a real-world scenario requiring students to employ their understanding of resultant forces and force resolution to solve it. Figure 6 illustrates a sample of the back and front of a Task Card. These questions are meticulously aligned with the upper secondary Physics syllabus. Among the 24 questions, eight are relatively straightforward, involving resolution of forces into either their x or y-components. The complexity of the remaining questions increases gradually. In these instances, students are required to break down forces into two components and compute the resultant force, mass, or acceleration of the object in question. These tasks encourage students to engage in higher-order thinking, as they must apply their knowledge and critically analyse the scenarios to address the associated problems effectively.

![Image of Task Card](image)

**Figure 6. A Sample of the Back and Front of a Task Card**

Students can seek help if they encounter challenges when attempting to solve a randomly selected Task Card. They can turn in the Task Card, the corresponding tile card, and one heart token. Other students who can solve the problem can volunteer to help. However, only those who can effectively explain and ensure their peers understand the solution are rewarded with a heart token and the opportunity to place a tile on the board, which advances their progress toward the boarding room. This dynamic encourages the development of students' communication and social skills throughout the game while promoting collaborative learning.

### Results

Following the MEEGA+KIDS model, the primary aim is to assess the usability and player experience of the board game as perceived by upper secondary school physics students. The data collected was analysed based on each analysis question.

**Is the board game attractive and user-friendly?**

Based on the results shown in Table 1, all the mean values fall between the range of 3.01 – 4.00, indicating a high average in students' agreement with the usability of the board game. The majority of the students found that the design of the board game is attractive and the game material colours and fonts match, with an average mean value of 3.98. At the same time, the students pointed out that the board game has high operability because it has clear and understandable rules (\( \bar{x} = 3.95, SD = 0.87 \)) and is easy to play (\( \bar{x} = 4.00, SD = 0.95 \)). Additionally, the board game is easily accessible as
the size and style of letters used are legible ($\bar{x} = 3.93, SD = 0.96$), and the colours used are understandable ($\bar{x} = 3.90, SD = 1.16$). Besides, students claimed that learning to play this board game was easy, with a mean value of 3.85 and SD = 1.17.

**Table 1. Mean Values for the Usability of the Board Game**

<table>
<thead>
<tr>
<th>Usability Dimension</th>
<th>Item</th>
<th>Mean, $\bar{x}$</th>
<th>Standard Deviation, SD</th>
<th>Average mean</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetic</td>
<td>The game design is attractive (board, cards, etc.)</td>
<td>3.98</td>
<td>0.99</td>
<td>3.98</td>
<td>High average</td>
</tr>
<tr>
<td></td>
<td>Game material colours and fonts match.</td>
<td>3.98</td>
<td>0.88</td>
<td>3.92</td>
<td>High average</td>
</tr>
<tr>
<td>Accessibility</td>
<td>The size and style of letters used in the game are legible.</td>
<td>3.93</td>
<td>0.96</td>
<td>3.92</td>
<td>High average</td>
</tr>
<tr>
<td></td>
<td>The colours used in the game are understandable.</td>
<td>3.90</td>
<td>1.16</td>
<td>3.85</td>
<td>High average</td>
</tr>
<tr>
<td>Learnability</td>
<td>Learning to play this game was easy for me.</td>
<td>3.85</td>
<td>1.17</td>
<td>3.85</td>
<td>High average</td>
</tr>
<tr>
<td>Operability</td>
<td>The game rules are clear and understandable.</td>
<td>3.95</td>
<td>0.87</td>
<td>3.98</td>
<td>High average</td>
</tr>
<tr>
<td></td>
<td>I consider that the game is easy to play.</td>
<td>4.00</td>
<td>0.95</td>
<td>3.98</td>
<td>High average</td>
</tr>
</tbody>
</table>

**Does the board game offer students a positive player experience?**

The mean and standard deviation for each item in the player's experience factor are shown in Table 2. Based on the results in Table 2, a highly positive player's experience has been detected. There are a total of six dimensions of the board game being evaluated. All six dimensions have an average mean value between 3.01 and 4.00, indicating a high average agreement on the statements provided in each dimension.

Overall, this board game provides players with a good sense of satisfaction. Students reached a high average agreement (average mean = 3.75) that they were satisfied learning through the game-playing process and would recommend this board game to their friends. Besides, most students evaluated this board game as an excellent social interaction platform where they could interact with other players ($\bar{x} = 3.85, SD = 1.01$) and cooperate or compete with others to complete the tasks ($\bar{x} = 3.98, SD = 0.94$).

Furthermore, the majority agreed that playing the board game was fun and preferred learning from the game over other teaching methodologies, especially the traditional lecturing method ($\bar{x} = 3.76, SD = 1.14$). The students highly agreed that they learned about the topic of the Resolution of Forces with the board game ($\bar{x} = 3.80, SD = 0.98$), and they were clear about how the board game is related to the physics content ($\bar{x} = 3.76, SD = 1.04$). Hence, this board game is highly relevant to the students.

However, the board game appeared to be less challenging as most students (58.6%) found the game monotonous in its tasks with repetitive challenges, with a low mean value of 3.15, SD = 1.24, agreeing that the game tasks are not repetitive and boring. Hence, most students (64.4%) did not become so engrossed in the game that they lost track of time, with the lowest mean value of 3.10, SD = 1.16.
Table 2. The Mean Value for each Item in the Quality Factor of Players' Experience.

<table>
<thead>
<tr>
<th>Player's Experience</th>
<th>Dimension</th>
<th>Item</th>
<th>Mean, $\bar{x}$</th>
<th>Standard Deviation, SD</th>
<th>Average Mean</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenge</td>
<td></td>
<td>The game is challenging enough for me.</td>
<td>3.27</td>
<td>1.25</td>
<td>3.31</td>
<td>High average</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The game offers new challenges (new obstacles, situations or variations) at an appropriate pace.</td>
<td>3.51</td>
<td>1.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The game does not become monotonous in its tasks (repetitive or with boring tasks)</td>
<td>3.15</td>
<td>1.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td></td>
<td>Completing the tasks of the game gave me a feeling of satisfaction.</td>
<td>3.68</td>
<td>1.13</td>
<td>3.75</td>
<td>High average</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I feel satisfied with the things I learned in the game.</td>
<td>3.80</td>
<td>1.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I would recommend this game to my friends.</td>
<td>3.78</td>
<td>1.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Interaction</td>
<td></td>
<td>I was able to interact with other people during the game.</td>
<td>3.85</td>
<td>1.01</td>
<td>3.88</td>
<td>High average</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The game promises moments of cooperation and/or competition among the players.</td>
<td>3.98</td>
<td>0.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I felt good interacting with other people during the game.</td>
<td>3.80</td>
<td>1.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fun</td>
<td></td>
<td>I had fun playing the game.</td>
<td>3.76</td>
<td>1.14</td>
<td>3.74</td>
<td>High average</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Something happened during the game that made me smile.</td>
<td>3.71</td>
<td>1.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Focus Attention</td>
<td></td>
<td>There was something interesting early in the game that captured my attention.</td>
<td>3.71</td>
<td>1.08</td>
<td>3.41</td>
<td>High average</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I was so involved in the game that I lost track of time.</td>
<td>3.10</td>
<td>1.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relevance</td>
<td></td>
<td>The content of the game interests me.</td>
<td>3.41</td>
<td>1.18</td>
<td>3.68</td>
<td>High average</td>
</tr>
<tr>
<td></td>
<td></td>
<td>It is clear to me how the content of the game is related to this topic.</td>
<td>3.76</td>
<td>1.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I learned the content with this game.</td>
<td>3.80</td>
<td>0.98</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I prefer to learn from this game than in other ways (eg. Lectures)</td>
<td>3.76</td>
<td>1.14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Does the board game foster students' learning in solving problems related to resolution of forces?

In order to investigate the effectiveness of the board game in fostering students' learning in solving problems related to resolution of forces, a comparative pre-test and post-test scores were conducted. The total marks for both the pre-test and post-test are 10. Table 3 shows the mean score for the pre-test is 2.27, with a standard deviation of 1.29, indicating that students did not perform well in the pre-test.
On the other hand, after the intervention, students' post-test scores improved drastically, as it is clearly shown in Table 3 that the mean score for the post-test is 7.56, with a standard deviation of 1.57. Since the mean score for the post-test is much higher than the pre-test score, it shows that the board game effectively facilitates students in solving problems related to resolution of forces.

<p>| Table 3. Paired Samples T-Test Results: The Comparison of the Pre-Test and Post-Test Scores |
|----------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean, $\bar{x}$</th>
<th>Std. Deviation (SD)</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test scores (10%)</td>
<td>41</td>
<td>2.27</td>
<td>1.29</td>
<td>-16.71</td>
<td>0.000</td>
</tr>
<tr>
<td>Post-test scores (10%)</td>
<td>41</td>
<td>7.56</td>
<td>1.57</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A paired sample t-test analysis was conducted to determine whether there was a statistically significant difference between the pre-test and post-test scores. The pre-test and post-test scores are statistically significant since the p-value is 0.000 ($p < 0.05$), indicating that students' improvement in the post-test is likely due to the usage of the board game.

**Discussion**

The present study investigated the quality of the board game and its effectiveness in fostering students' learning for the topic of Resolution of Forces. As demonstrated in the results of this study, a well-designed board game can be attractive and user-friendly. When an educational game is designed and developed based on students' needs, focusing on specific learning objectives according to the physics syllabus and considering the three major factors: cognitive, affective and socio-cultural, it would be able to meet the students' expectations.

Besides, the findings suggest a favourable evaluation of the board game where students expressed a highly positive player experience. During the workshop, we observed that students participated actively in the game and viewed it as an enjoyable learning activity. Furthermore, the board game's mechanics stimulated healthy student competition and promoted social engagement among players in a tangible, real-world environment.

During the gameplay, it was observed that some students asked for help from their peers and voluntarily helped others to solve the problems due to the game mechanics and rules setting of the board game. Through this process, indirectly, the board game fosters collaborative learning and peer interactions. Peer collaboration emerged as a valuable support mechanism to enhance individual learning outcomes (Vygotsky, 1978; Niu et al., 2018). Hence, board games can catalyse social interaction, draw players' focus to the board game events and foster a stronger connection between players and the game's educational objectives.

Moreover, establishing appropriate rules and mechanisms to encourage peer feedback and interaction during student collaboration is crucial for successfully improving students' academic performance (Gielen & De Wever, 2015). Hence, researchers and game designers should investigate methods for incorporating different game mechanics and how these mechanics synergise with the subject matter to create meaningful social engagement. This finding aligns with the observations made by
Tsarava et al. (2018), who noted that students felt capable and deeply engaged during gameplay, experiencing a positive emotional response.

On the other hand, in this study, some students claimed that the challenges provided were slightly monotonous as they were required to solve real-world problems throughout the gameplay. Modifications could be made to improve this situation by introducing extra rules or adjusting the problem-solving tasks by incorporating alternative activities. According to Dziob (2020), it is expected that a game's activities, rules, and scoring system will be modified to suit a specific group of students. Different groups of students may have different expectations and needs.

Meanwhile, the pre and post-tests were used to verify the improvement in learning the topic of Resolution of Forces, and the findings showed that students' academic performance improved after using the board game. The difference between the mean pre-test and post-test scores was significant at the level of 0.05, indicating the usage of the board game positively affects the problem-solving skills development of the students when dealing with problems of resolution of forces.

Scholars proposed that the integration of gamification and GBL could enhance students' learning experience, as observed through the improvement in students' post-test scores (Dicheva et al., 2015 & Sadler et al., 2013). This study showcases how a well-designed board game can significantly enhance students' learning, especially in physics. Other studies have yielded comparable findings, where the usage of board games enhanced students' learning in the physics area as well (Cardinot & Fairfield, 2019; Mohammad Yusoff et al., 2023).

Additionally, with the aids of the visual representation tool, as shown in Figure 5, the gadget that can assist students in breaking down forces into x and y-components facilitated students learning, particularly those who struggle with understanding the abstract concepts found in books and via conventional teaching methods. This likely promotes deeper understanding and better retention in learning the concept of resolution of forces.

For a board game to be effective, it should feature well-defined rules, offer a compelling reason for collaboration, present a challenging experience for players, and offer a variety of activities and experiences.

**Conclusion and Recommendations**

This article discusses the design and development, implementation, and assessment of a board game created to enhance comprehension of the concepts of resolution of forces among upper secondary school students. Overall, the evaluation of the board game regarding player experience, usability, and learning is positive. It can offer more than just an engaging learning environment to the students but a platform that promotes social interactions among the students. Based on the results, it can be concluded that the introduction of the Catch the Flight board game was effective, as it significantly influences the enhancement of students' learning and problem-solving skills for resolution of forces. The educational goals were met without the reliance on computers, even though the current trend is more toward integrating digital games. This encourages broader utilisation of the educational board game in teaching physics at the upper secondary school level. Educators must be aware of the quality of the educational games used in lessons to ensure that the games help facilitate students' learning, motivation and social interaction. This study could be a reference for
designers interested in designing educational board games and stakeholders in determining the potential of non-digital educational games in teaching physics. Educators can make an effort to incorporate educational board games into their teaching of physics and other subject areas to enhance learning and provide students with a more engaging learning environment. Educators can also involve students in designing educational board games based on the curricular content. When students are actively engaged in the development of educational board games, it has the potential to promote learning and science outreach.

Conflict of Interests

No conflict of interest.

References


Chiarello, F., & Castellano, M. G. (2017). Board games creation as motivating and learning tool for STEM. In M. Pivec (Eds.), *Proceedings of the 11th European Conference on Game-Based Learning 2017* (pp. 71-78). Academic Conferences International Limited.


