Journal of Academia Vol. 11, Issue 1 (2023) 34 – 46

THE USE OF BOARD GAME TO ENHANCE TEACHING AND LEARNING ON SKETCHING FREE BODY DIAGRAM IN PHYSICS

Nurulhuda Mohammad Yusoff[1*], Siti Maisarah Aziz [1], Salmiah Jamal Mat Rosid [1], Aida Othman[1], Ismahafezi Ismail [2], Roslan Umar[3], Siti Noor Syuhada Muhammad Amin[1]

[1]UniSZA Science and Medicine Foundation Centre, Universiti Sultan Zainal Abidin, Gong Badak Campus, 21300 Kuala Nerus, Terengganu, Malaysia
[2]Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu, Malaysia
[3]East Coast Environmental Research Institute, Universiti Sultan Zainal Abidin, Gong Badak Campus, 21300 Kuala Nerus, Terengganu, Malaysia

[*]Corresponding author: nurulhudamy@unisza.edu.my

Abstract

The current state of education is witnessing a shift towards interactive learning experiences, moving away from the conventional approach of written essays presented through slide presentations or video stills. The term 'interactive' in the education sector encompasses a wide range of meanings, with students no longer limited to passive listening and note-taking, but instead learning through hands-on activities, internet access, and advanced technologies like Augmented Reality. The decline in the popularity of science education in recent years is largely attributed to the lack of mastery and requires a modern approach to sustain students' interest. To address this issue, a study was conducted to evaluate students' proficiency in sketching Free Body Diagram, depicting forces acting on an object, in accordance with Newton's Laws. The results revealed that students require learning aids to enhance their understanding of sketching Free Body Diagram. In response to this, a prototype of MyForce@FBD, a learning tool, has been developed with a gamification concept, combined with an Augmented Reality application, to emphasize the basic concepts of force and hands-on sketching. The primary aim of this project is to improve students' sketching skills, starting with elementary sketchings and progressing to more complex illustrations, to help them comprehend how forces act on objects according to Newton's Law. The development of such projects is crucial in diversifying learning and teaching techniques in line with the IR4.0 Education revolution.

Keywords: Board game, Augmented Reality, Free Body Diagram, Force, Physics

Article History:- Received: 14 December 2022; Revised: 28 March 2023; Accepted: 29 March 2023; Published: 30 April 2023

Introduction

Nowadays, the strengthening of science education is one of the important agendas to increase the future specialist scientists, technologist and engineers. It is important to identify young individuals with special talents early on so that they have the opportunity to grow and develop their abilities over time. Science education receives a big challenge starting from student at school age. Since that, science educators should be creative person in developing module and delivering tools to ensure students' full engagements during the learning and teaching process. Gamification based on board games is one of the best approaches in enhancing the effectiveness of the learning and teaching process. Teaching and learning using gamification tools offers tremendous opportunities as compared to the traditional method in order to deliver knowledge. The use of gamification as an approach to imparting knowledge can enhance student motivation, while also making the learning process more engaging, enjoyable, and interactive (Kusuma et al., 2018).

In line with that, gamification is defined as the use of game design elements in non-game contexts with the objective to motivate and increase user activity and retention ([a]Deterting et al., 2011; [b]Deterting et al., 2011). Kapp et al., (2012) proposed that gamification is using game-based mechanics, aesthetics, and game thinking to engage people, motivate action, promote learning, and solve problems. Hamari et al., (2014) reported that gamification implements motivational affordances, resulting in psychological outcomes which for their part cause further behavioural outcomes. Game based learning was introduced as a teaching method in language learning dates back to the 19th century, math in the 1960s, Science since the early 20th century and social studies since 1960s (Kapp et al., 2012). The type of gamification can be like digital game, computer game, card game, board game and so on (Khoushaini et al., 2021). Gamification provides significant advantages over traditional scholastic systems, offering numerous opportunities to enhance learning experiences (Oyshi et al., 2018). Basically, board games are designed with attractive visuals which entice students to play and learn at the same time.

Board games can be used as an educational tool to teach physics concepts, but their usage still in limited in some respects such as for the simulation, experimental task or presenting real world Physics phenomena. Despite these limitations, board games can still be a valuable tool for teaching Physics concepts in a fun and engaging way. Board games can provide a visual and interactive way to explore physics concepts, and can help students develop critical thinking and problem-solving skills (Millar et al., 2016). Some popular Physics-themed board games include "Quantum," "Gravity Maze," and "Physics Fluxx.".

Force is a fundamental concept in Physics that describes the interaction between two objects or systems, and it is central to many areas of Physics, including mechanics, thermodynamics, and electromagnetism. The topic of force in Physics can be challenging for many students to understand since it is related to vector quantity. This can be confusing for students who are used to dealing with magnitude and direction to represented a vector component. Additionally, there are many different types of forces, such as friction, gravity, normal forces, each with their own unique properties and characteristics. To help students understand the concept of force, it can be helpful to use real-world examples of course and hands-on activities through gamification to illustrate how forces work in different contexts. As a strategy, a questionnaire has been distributed to collect the data of student experience in learning force. It shows that students are experiencing difficulty in mastering the concept of force acting on an object in the form of a Free Body Diagram. One of the issues with sketching Free Body Diagram among students is that they often struggle to understand the concept of force acting on an object and how to accurately depict it in a diagram. This may be due to a lack of practice, inadequate guidance or instruction, or difficulty in visualizing the forces at play in a given situation.

Thus, a prototype called as MyForce@FBD has been developed as a learning tool applying gamification concept with the combination of Augmented Reality (AR) application in order to emphasise the basic concept of force and hands-on sketching force on Free Body Diagram (FBD). The main goal of this project was to improve students' sketching FBD skills, starting with basic sketching and progressing to more complex sketching, in order to help students better understand a force acting on an object according to Newton's Law. This project's development is also a means of diversifying learning and teaching techniques in line with the IR4.0 Education revolution.

Methods

Projects Framework

The research methodology consists of three phases, which are outlined below.

Phase 1 Questionnaire Distribution

- A questionnaire was distributed to assess student needs. In this phase, the research focus on the data obtained from the questionnaire.

Phase 2 Designing process

- The design process including gamification prototype, navigation map and storyboard of the entire content of the gameboard. In addition, interface content was designed such as creating a virtual button framework, virtual diagrams, and prototype models in accordance with user targets.

Phase 3 Augmented Reality Development

- The content of Augmented Reality was eveloped to present images of the answers for three levels of difficulty-easy, intermediate, and hard.

Phase 1: Questionnaire Distribution

The present study randomly enrolls students from the Foundation, Matriculation, and Diploma programs. The investigation involved a total of 85 students, and to assess their requirements concerning the topic of force and sketching Free Body Diagram, a questionnaire was distributed. The survey included 5 questions regarding self-efficacy and perception of the subjects presented. The feedback provided by them was highly valuable in the development of the board game.

Phase 2: Designing Process

MyForce@FBD Prototype

A prototype for gamification has been created, which involves designing an interface with virtual buttons, diagrams, and prototype models that adhere to user requirements and virtual graphics standards. The content of this gamification is equipped with three level of difficulty - easy, intermediate, and hard. Augmented Reality (AR) technology is utilized to show the answer for all levels of questions. This game has been created to be playable either individually or in a group, with a maximum time of 15 minutes. The player who accumulates the highest number of honeycombs in the game will be declared the winner. Figure 1 displays the complete set of MyForce@FBD board game prototype. The design of the prototype is based on the references of Saidina.

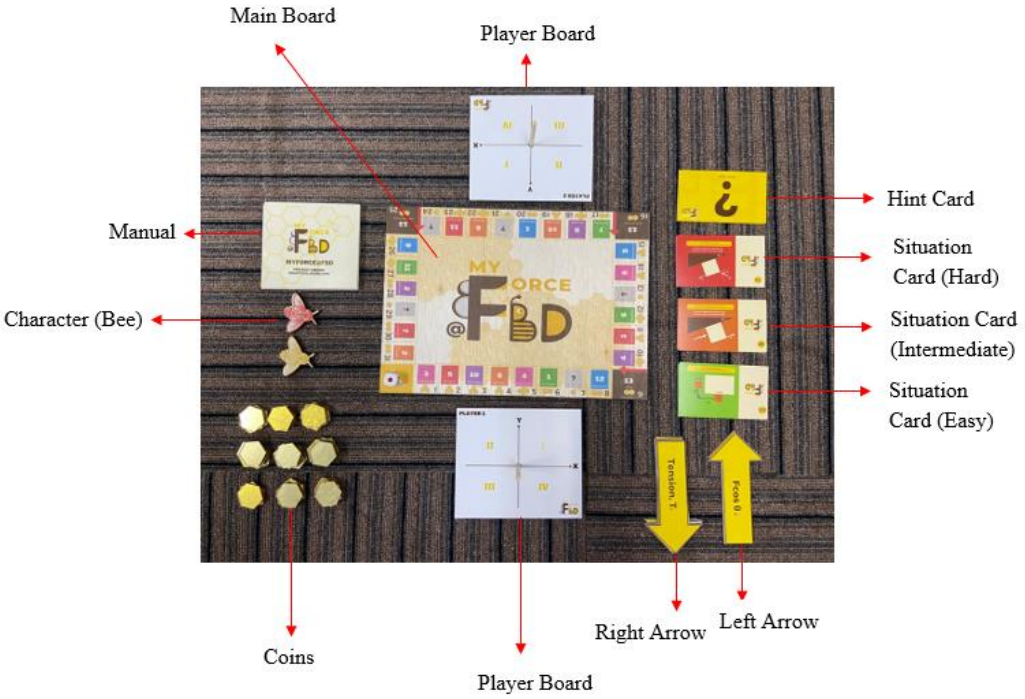


Figure 1. Complete set of MyForce@FBD board game prototype

Main board

Figure 2 displays the main board, which is designed with vibrant colors to capture the players' attention. The board is made up of 32 columns, starting with the start column. One column contains a question mark, which provides a hint or clue. Each column typically includes three components: a number in a colored square, a statement indicating whether the situation involves friction or non-friction, and a number in a white square. The number in the colored square represents the situation number, which players will need to answer later. The statement denotes whether the situation involves friction or non-friction, and each situation is assigned a score that is indicated on the board.

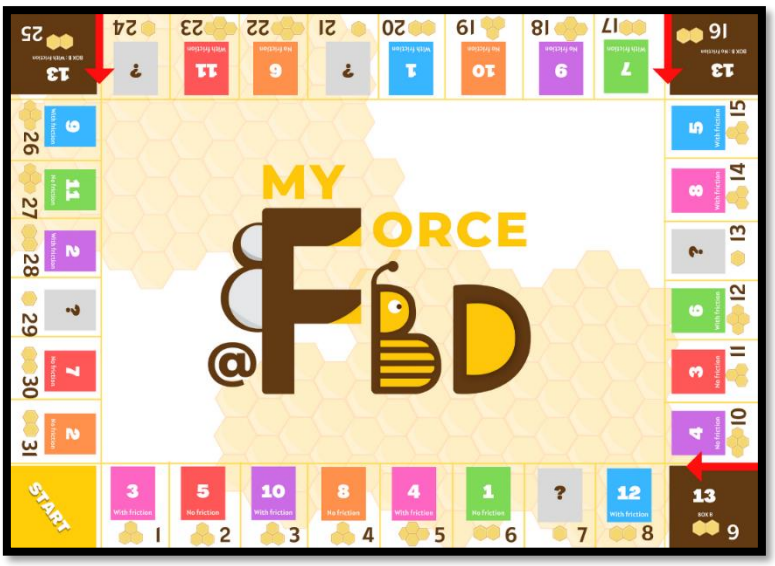


Figure 2. Main Board Game

Situation Card

The situation cards present a range of questions with varying levels of difficulty, indicated by their categorization as Easy, Moderate, or Hard in Figures 3(a), 3(b), and 3(c), respectively. The player is required to answer the question corresponding to the number on the box. The questions are self-explanatory and players are given 2 minutes to answer them during their turn. Once a group or individual player has answered, the turn passes to the next group. In case the answer is incorrect, the group will not be awarded the full token, and they will not be given another chance to attempt the same question. At the end of all rounds, the groups count the number of tokens they have accumulated, and the winner is the group that has successfully collected the most coins.

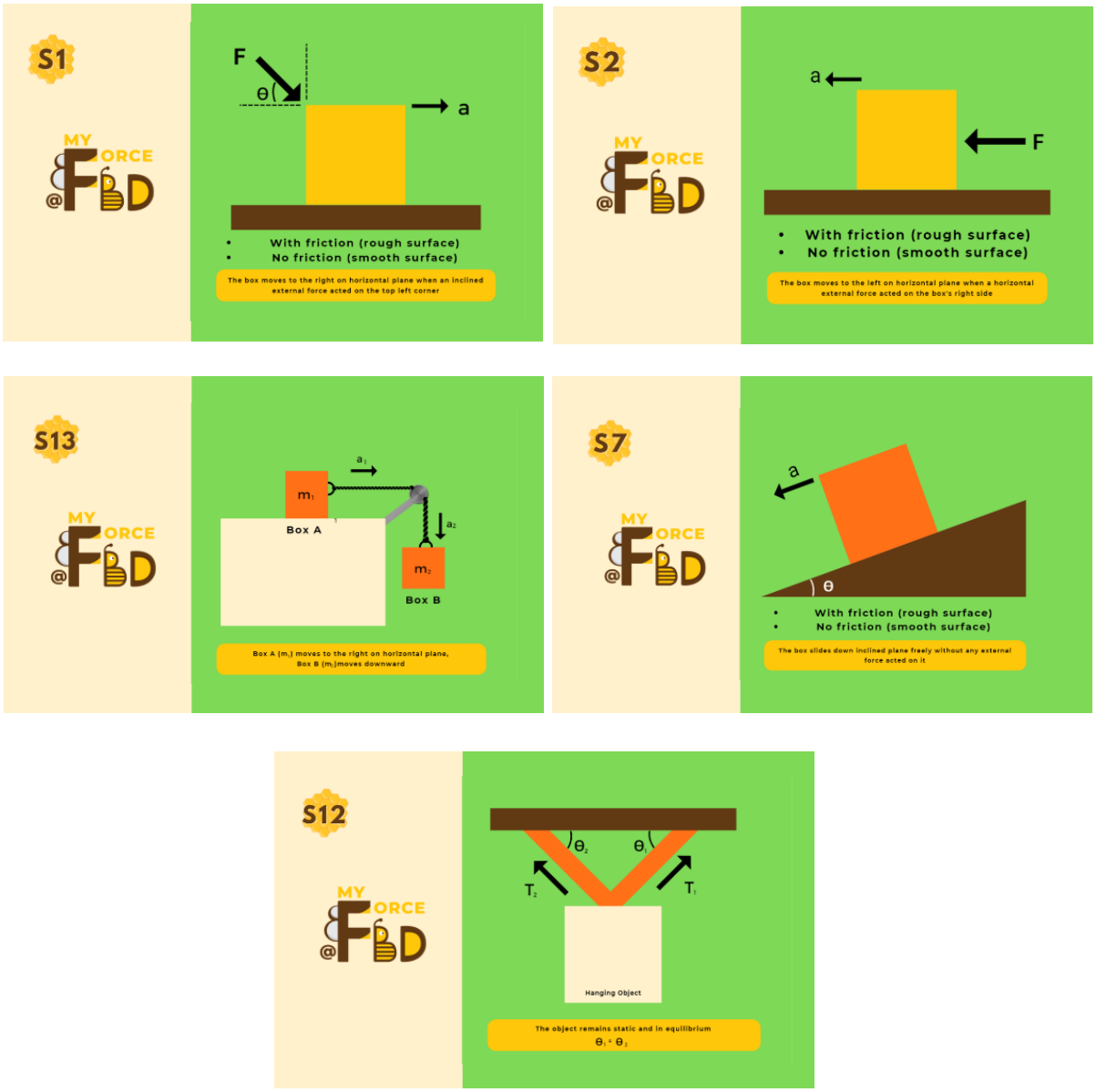


Figure 3(a). Easy Level

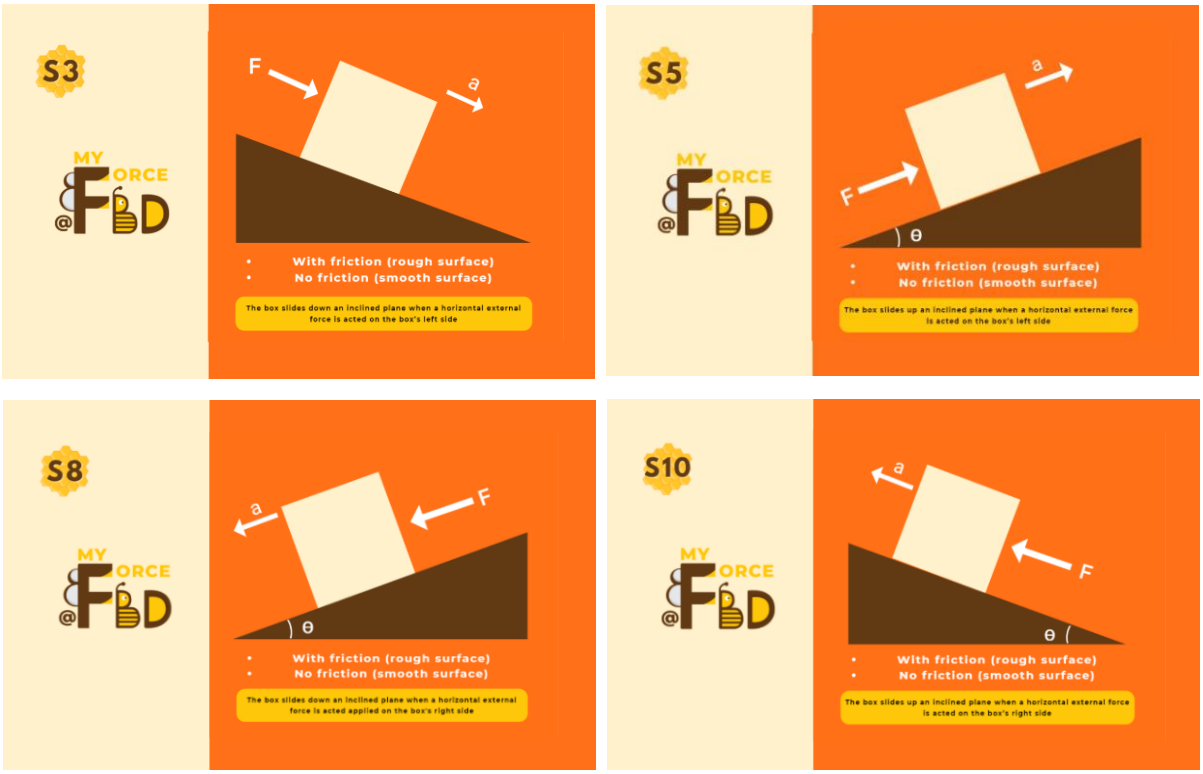


Figure 3(b). Intermediate Level

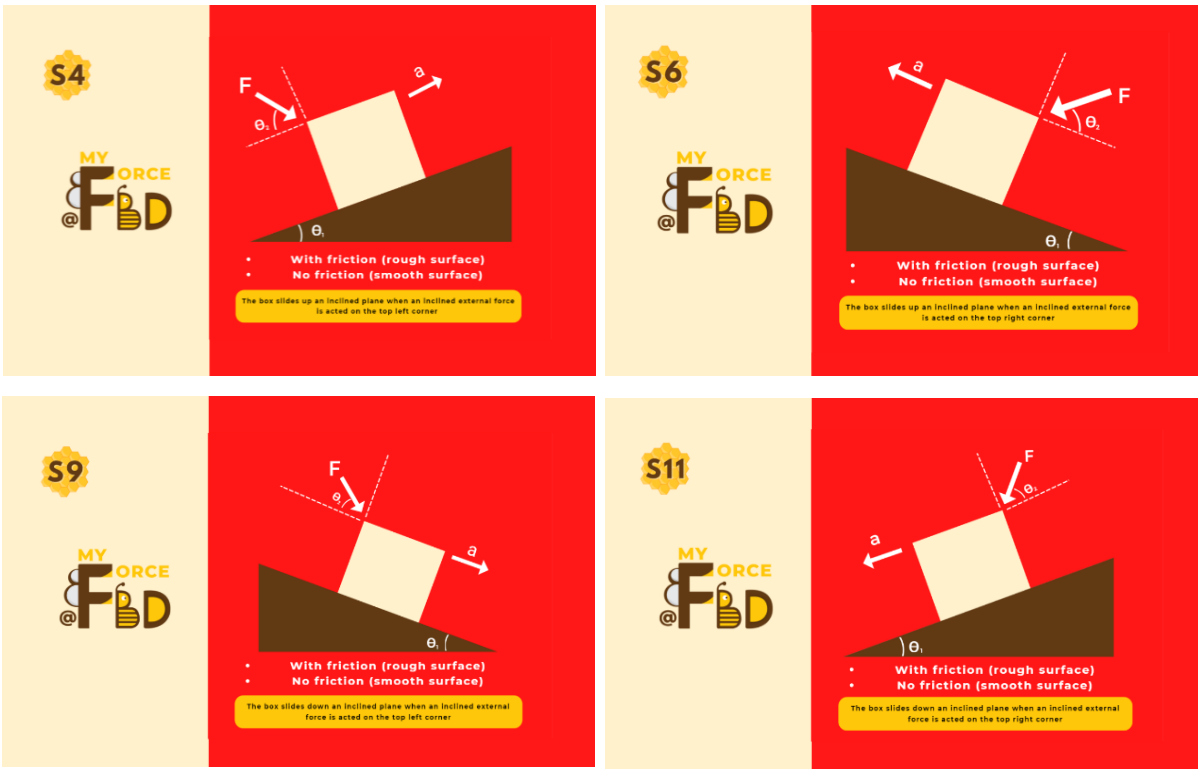


Figure 3(c). Hard Level

Player FBD Board

Figure 4 displays two Free Body Diagram (FBD) boards, marked as x-axis and y-axis. Players must correctly arrange the force arrow on the respective board to present their answer.

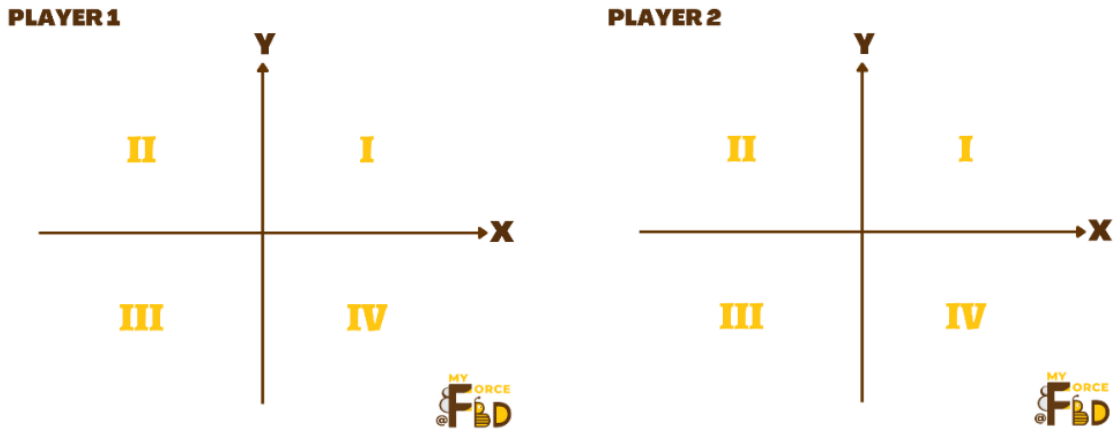


Figure 4. FBD's Player Board

Arrows

Figure 5 (a) and Figure 5 (b) show a set of force arrows that players use while answering questions or situations. These arrows, along with the free body diagram board, aid players in solving the problems presented to them.

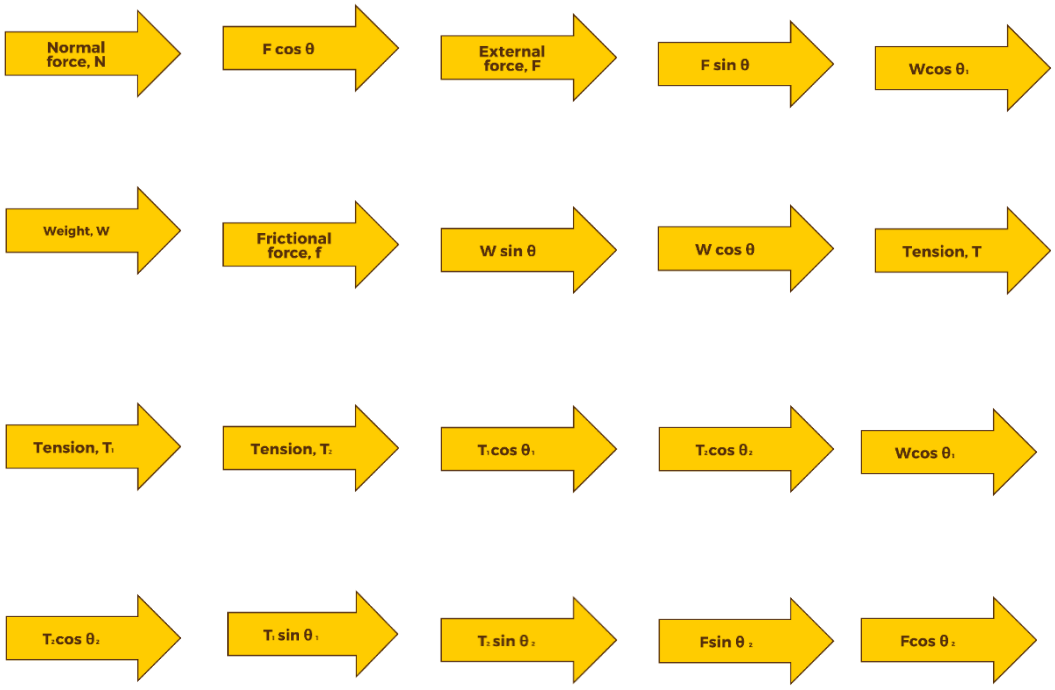


Figure 5 (a). Right Arrow

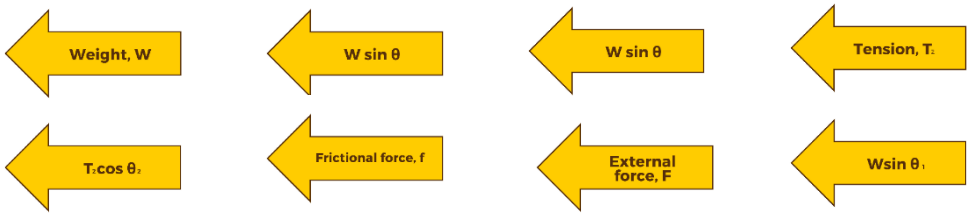


Figure 5 (b). Left Arrow

Hint Card

Figure 6 displays the hints included in the board game. If a player rolls the dice and lands on the hint column, they get to keep the hint. However, if another player wishes to buy the hint, they can do so for a cost of 1 gold coin. Once purchased, the player can view the hint, but they must return it to the referee after use.

Figure 6. Hint Cards

Honeycomb Coins as Token

Gold honeycombs are used as tokens for players, as illustrated in Figure 7. Upon successfully completing the free body diagram on the free body diagram board, the player is rewarded with honeycombs. If the player accurately identifies all the arrows, they receive the full honeycomb value as specified on the board. However, players will lose one honeycomb for every incorrect arrow, and only the banker (the referee) can award honeycombs for correct arrows.

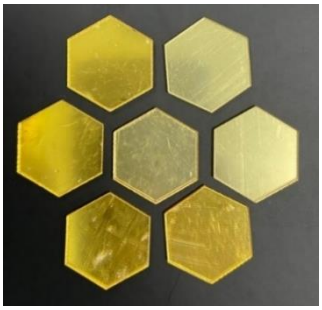
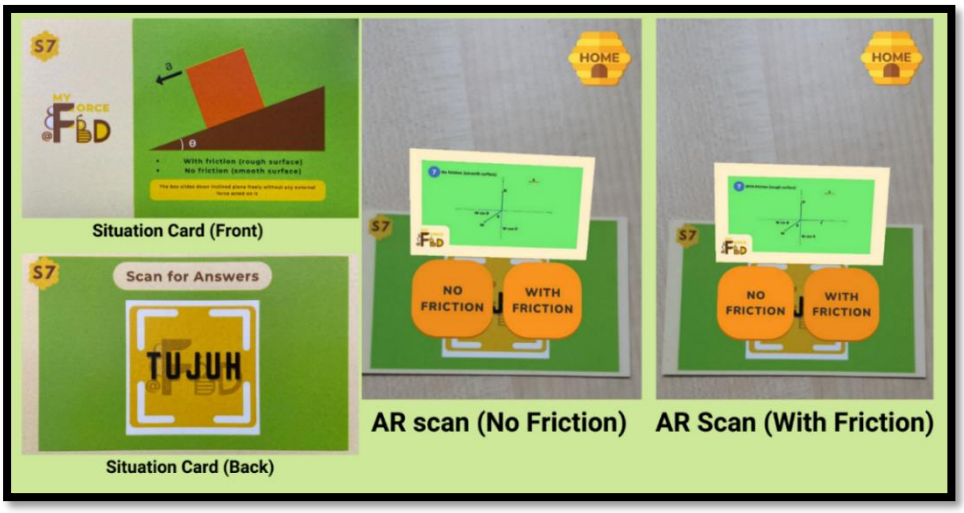


Figure 7. Honeycomb shape of coins

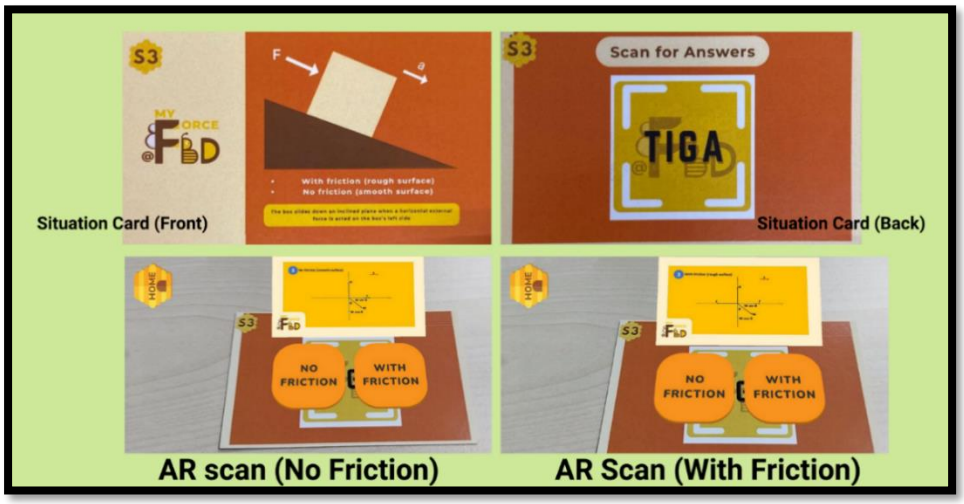
Phase 3: Augmented Reality (AR) Development

There is a scanning image of each situation provided to check the answer after the players finish sketching the Free Body Diagram as shown in Figure 8. The image of the answer will be displayed in the form of Augmented Reality (AR) as shown in Figure 9.

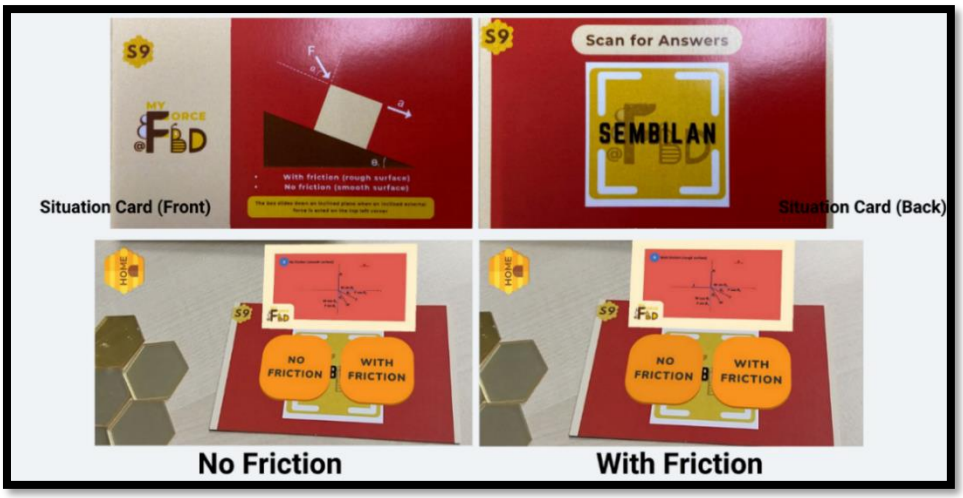
Figure 8. Scanning image for answer using the application of Augmented Reality (AR)



(a) Easy Level



(b) Intermediate Level



(c) Hard level

Figure 9. Answer presented through Augmented Reality (AR) images

Result and Discussion

A survey was conducted among 85 respondents, consisting of Diploma, Matriculation, and Foundation Level students to gather their opinions on the use of gamification in practicing the sketching Free Body Diagram. Figure 10 shows the percentage of respondents involve in this study.

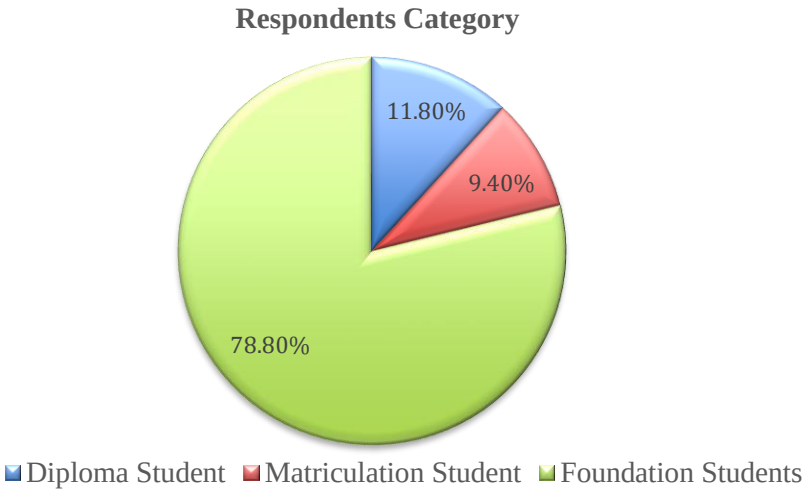


Figure 10. Level of Education (85 respondents)

Table 1 shows the feedback provided by respondents for each statement. The first statement indicates that most of the respondents, 65.9% have some level of interest in the subject of Physics, with only 9.4% of them reporting a high level of interest and 22.4% expressing a lack of interest. It should be noted that Physics is commonly considered a challenging subject in school since Physics typically employs mathematical analysis to explore the fundamental characteristics of the natural world (Gurikar, 2015). Nevertheless, there is a need to increase the percentage of students who are highly interested in studying Physics while decreasing the proportion of those who are not interested, as Physics is closely linked to the development of STEM education.

The second statement pertains to the perceptions of respondents on the topic of force, which the result is closely related to the first statement. Approximately 64.7% of the respondents found the topic of force to be easy, with only 2.4% finding it very easy, while 32.9% considered it difficult. These findings suggest that students with a high level of interest in Physics may find it easier to tackle problems related to force, as such problems involve motion and require the application of vector calculations. Since that, the results indicate that a larger number of students find that topic difficult compared to those who find it very easy.

The third statement relates to proficiency in creating Free Body Diagram (FBD) that display all the forces operating in a given scenario. The results indicate that, on average, 83.6% of respondents are capable of generating FBDs. This finding is somewhat unexpected, as only 8.2% of respondents struggle with FBD sketches, a figure that is equivalent to the number of respondents who excel in this area. However, the study suggests that there are still some inaccuracies in the students' FBD sketching since only 8.2% of them are deemed proficient in this task.

The fourth statement highlights the significance of Free Body Diagram in comprehending the concept of Force. According to the survey results, 80% of the respondents consider it very important, while 20% find it important. This finding leads to the fifth statement, which emphasizes the requirement of learning aids to understand and sketch Free Body Diagram. As per the survey, 55.3% of the respondents consider it very necessary, 42.4% find it necessary, and only 2.3% consider it not necessary. The small percentage of respondents who feel it is not necessary may be due to their ability to sketch Free Body

Diagram effectively. These results support the third statement, which suggests that only 8.2% of the respondents are very skilled in sketching Free Body Diagram. In general, the majority of students find learning aids to be extremely helpful in enhancing their ability to sketch Free Body Diagram and grasp the concept of force more effectively.

Table 1. Result of the questionnaire regarding to requirement of teaching and learning aid for topic of Force for 85 respondents.

No.	Statements	Student's Feedback	Percentage (%)
1.	Level of interest in learning Physics	Very Interested	9.4
		Somewhat interested	65.9
		Very not interested	22.4
		Not sure	2.3
2.	Perception of 'Force' Topic	Easy	64.7
		Very Easy	2.4
		Hard	32.9
3.	Ability to sketch Free Body Diagram	Poor	8.2
		Average	83.6
		Very Good	8.2
4.	The importance of Free Body Diagram to understand the topic of Force comprehensively.	Important	20
		Very Important	80
5.	The need for learning aids in understanding and sketching Free Body Diagram	Not Necessary	2.3
		Necessary	42.4
		Very Necessary	55.3

Conclusion

Teaching science using games actually faced many barriers due to difficulties in procedure and game design. Training by using games in delivering science information should be improved time to time. In order to increase student engagement, educators should be equipped with fundamental principles of game design to create diverse types of games. The significance of principles such as empathizing, defining, ideating, prototyping, and playtesting must be recognized. The task must be well described by considering both essential features of any educational game, such as rules, learning outcomes, and designing purposeful game mechanics, and the learning outcomes intended with the educational game resource. Incorporating digital games in the Physics classroom is essential to prevent students from becoming bored while learning. Thus, it is hoped that MyForce@FBD could increase the cognitive and functional work skills focusing on practical skill among students. Furthermore, it can assist students, from beginners to experienced learners, in the task of sketching Free Body Diagram.

Acknowledgement/Funding

The author would like to express gratitude to Universiti Sultan Zainal Abidin for providing funding for this research under Project Code UniSZA/2021/SoTL/09 which has enabled the implementation of this innovative study.

Author Contribution

N Mohammad Yusoff: Design of Board Game, SM Aziz – Create the flow of storyboard of game, I Ismail – Augmented Reality (AR) development, S Jamal Mat Rosid & SNS Muhammad Amin– Conducted the questionnaire, A Othman – Analysis of questionnaire data.

Conflict of Interest

None of the authors of this paper has a financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the paper. It is to specifically state that "No Competing interests are at stake and there is No Conflict of Interest" with other people or organizations that could inappropriately influence or bias the content of the paper.

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