Development of Board Game "Dynamic Dash" in Learning Force and Motion for Grade 12 STEM Learners

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ABSTRACT

The issue of low performance in science education, often attributed to low student engagement and insufficient instructional materials (IMs), has prompted various studies aimed at addressing this challenge. This study focuses on integrating a board game into the educational framework to enhance student engagement, specifically in the teaching of "Force and Motion," a challenging topic in Physics for Grade 12 STEM learners. The board game, titled "Dynamic Dash," was developed using the Successive Approximation Model (SAM), with iterative improvements based on feedback from science teachers and STEM graduates, ensuring alignment with the DepEd competencies. A developmental research design was employed, utilizing a mixed-methods approach. The study compared the performance of a control group (traditional lecture-based instruction) with an experimental group (incorporating the "Dynamic Dash" board game). Data analysis techniques included qualitative insights, mean computation for rating scales, and normalized gain for quantitative assessment. The "Dynamic Dash" board game received a "Very Good" rating from 20 in-service Science Teachers and 35 STEM graduate students, highlighting its effectiveness in addressing curriculum-relevant aspects. The study recommends implementing the game in classrooms and measuring student learning through pre-and post-tests to evaluate their understanding of force and motion.

Keywords: Force and Motion, Student Engagement, Science Education, Game-based learning. Board Game

INTRODUCTION

Low performance in science education is a multifaceted issue that has garnered significant attention in recent years. Various studies indicate that this issue is often linked to low student engagement and insufficient instructional materials (IMs). For instance, a study by Wang and Degol (2017) used a sample of 1,200 high school students and found that only 35% of students reported high engagement in science classes, while 45% reported moderate engagement, and 20% reported low engagement. They found that low engagement significantly impacts science performance. Students with low engagement reported lower science grades and test scores. Specifically, students with low engagement scored 15% lower on average in science assessments compared to their highly engaged peers. The authors suggest that engagement is a multifaceted construct encompassing behavioral, emotional, and cognitive dimensions. Enhancing student engagement through positive reinforcement, relevant curriculum, and interactive teaching methods can significantly improve science performance. Moreover, a study by Fredricks et al. (2016) surveyed 800 middle school students, revealing that 30% of students felt disengaged in their science classes, which correlated with a 20% lower average score on science tests compared to engaged students. The study demonstrates that students with low engagement in science tend to have lower academic outcomes. It found that students who were less engaged were twice as likely to perform below the proficient level on standardized science tests. Addressing these

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challenges requires a comprehensive understanding of the underlying causes and the implementation of effective strategies to enhance student performance. In response, educators have begun to explore innovative approaches, including the integration of board games into the curriculum. Board games offer a unique opportunity for hands-on, experiential learning, allowing students to interact with physics concepts in a dynamic and engaging manner. Researchers found out that there are various teaching strategies to make the physics class exciting and interesting. It includes simulation, gamification, game-based learning, etc. Among the three, game-based learning is known to be the most used by the teachers. In addition to constructing games for students to play, it also focuses on designing instructional activities that can gradually introduce ideas and direct learners toward a certain objective (Dinscore & Pho, 2015). Several studies conducted between 2015 and 2024 provide compelling evidence supporting the use of board games as effective tools for teaching force and motion concepts. One such study by Dziob (2018) investigated the use of a board game to assess students' learning in waves, vibrations, and optics. The experimental group, which participated in the board game activity, demonstrated significantly higher post-test scores compared to the control group. Additionally, students reported positive attitudes toward the game-based assessment method, indicating reduced test anxiety and increased motivation for learning. This research highlights the potential of board games to engage students and enhance their understanding of complex physics concepts.

The primary objective of this study is to develop and determine the effectiveness of the dynamic dash board game in improving the understanding of force and motion among grade 12 STEM learner in STI College-Iligan City in the Philippines.

METHODS

Research Design

This study employed a Research and Developmental framework with a mixed method of qualitative and quantitative support in developing the board game. The researcher utilized this research design with aims to outline the process of developing and implementing board games. The qualitative data was gathered through the administration of a survey questionnaire after the exposure of learners to the board game. In the quantitative method, the researcher used specifically the quasi-experimental approach in which the experimental group and control group would be part of the study evaluating the effects of implementing the developed board game through achievement tests. With the aid of the modified instrument, the researchers would like to find out if a significant difference appears in the pretest and posttest scores of the two groups and the gain scores in the result of pretest and posttest between the two groups.

Research Subjects and Participants

The study involved two sections of Grade 12 STEM students from STI-College Iligan City.To be included in the study, students needed to meet these criteria: (a) be enrolled in the Grade 12 STEM strand, (b) have their parents' or guardians' consent, and (c) not have any medical conditions that could affect their learning. Additionally, the board game packet was reviewed and improved based on feedback from 20 physics experts or science teachers, as well as a group of STEM graduate students, before it was used in the study.

Data Gathering Procedure (Successive Approximation Model)

The data gathering procedure unraveled through a comprehensively structured process, commencing the assessment analysis of SAM involving twenty (20) teachers and thirty-five (35) STEM graduates students for the most complex physics topic to teach and learn respectively advancing through design and development with the validation of the board game packet and culminating in the implementation and evaluation phase.

Preparation Phase

The information gathering process marked the start of the study. It involved collecting important data to help design and develop the board game for teaching physics concepts. The researcher conducted interviews with

20 science teachers, either online or in person, depending on their availability, to rank the physics topics in General Physics 1 for the first semester from the most difficult to the easiest to teach. Additionally, 35 STEM graduate students were asked to rank the topics from the hardest to easiest to learn. The rankings were based on the competencies from the Department of Education's Most Essential Learning Competencies in the Curriculum Guide. This

Iterative Design, Development and Validation of Dynamic Dash Board Game

The board game was the main playing surface, where players moved along a path, similar to games focused on ethical consumption and math (Ji et al., 2019; Mae & Woo, 2019). It was inspired by commercial games like Snakes & Ladders and was based on specific learning goals, challenges, and rules. Different types of cards (such as trivia, command, and resource cards) introduced tasks that made the game more engaging and helped improve learning outcomes (McSween, 2016). The researcher designed characters for players to move around the board based on game rules, such as answering quiz questions correctly (Ji et al., 2019). The game board featured about fifty to eighty tiles, some with actions or consequences that made players advance, stay in place, or move back.The game focused on force and motion, combining physics concepts into a fun and interactive experience. Players moved through the board, facing real-world physics challenges like Newton’s Laws, acceleration, momentum, and forces such as tension and gravity, with the goal of reaching the finish line by using their physics knowledge.

The game’s development followed important design principles to ensure it worked well in classrooms. Since games are social activities, the environment of the game is as important as the players themselves. To fit classroom use, the following factors were considered: (a) time limits, making sure the game could be played within a single class period (Cooke et al., 2020); (b) game mechanics, which dictate how players move and interact in the game. These mechanics can vary in complexity depending on the designer’s experience and may introduce extra challenges in making educational games (Cooke et al., 2020); and (c) challenges and limitations, like rules that keep the game engaging without interrupting the learning process (Cardinot et al., 2022). Common limitations include time, number of players, game pieces, and movement restrictions per turn.

Once the board game packet was created, it went through a validation process during its development. Experts in the field, including 8 Physics experts and 12 science teachers, reviewed the final version to ensure the accuracy of the content, including the board game design, card colors, mechanics, achievement test, and lesson plan. The overall design and game elements were evaluated using a rating scale and feedback form. All suggestions were incorporated into the final board game packet. During this phase, the researcher made three rounds of revisions to improve the game.

Data Analysis

To analyze the collected data, various statistical methods were used. Thematic analysis was applied to review the qualitative data from the comments, suggestions, and survey feedback. The rating scale and motivation questionnaire were examined using mean calculations to provide a numerical view of the board game's effectiveness. Additionally, normalized gain was used to measure the improvement in participants' scores after using the board game.

RESULTS AND DISCUSSIONS

Preparation Phase

The researcher conducted a survey to find out which science topic is the hardest for Grade 12 STEM students, following the K to 12 Curriculum. Both science teachers and students participated through online platforms like Messenger. For teachers, the survey included key learning areas from the Department of Education's science curriculum. Out of 20 physics teachers, 30% (6 teachers) identified Newton's Laws of Motion and Applications as the most difficult topic to teach. Kinematics: Motion in 2D and 3D was the second hardest, chosen by 25% (5 teachers), while 15% (3 teachers) found Vectors challenging. Other topics like Linear Fitting of Data and Measurement were selected by fewer teachers. Similarly, 30% of students (9 students) also found Newton's Laws to be the hardest topic, followed by Vectors and Kinematics. Overall, the survey results show that Newton's Laws of Motion and its applications are the most challenging topic for both teachers and students.

Several recent studies emphasize that Newton's Laws of Motion, particularly their application, pose significant challenges for both teaching and learning. For instance, a study by Angell et al. (2020) found that students frequently struggle with conceptualizing and applying Newton's Laws due to the abstract nature of forces and motion. The research indicates that learners often hold onto misconceptions, such as confusing forces with energy or motion with causality, making it harder to grasp the interplay of forces in different contexts. Additionally, students have difficulty transitioning from textbook scenarios to real-world applications, which adds to their struggle in this area.

Table 1. Aligning the Board Game Packet with the DepEd K-12 Identified Standards and Competencies

CONTENT	CONTENT STANDARD	PERFORMANCE STANDARD	LEARNING COMPETENCIES	CODE
Newton's Laws of Motion and Applications	The learners demonstrate an understanding of...		The learners...	
	· Newton's Law's of Motion · Inertial Reference Frames Action at a distance forces · Mass and Weight · Types of contact forces: tension, normal force, kinetic and static friction, fluid resistance · Action-Reaction Pairs · Free-Body Diagrams · Applications of Newton's Laws to single-body and multibody dynamics · Fluid resistance		· Apply Newton's 1st law to obtain quantitative and qualitative conclusions about the contact and noncontact forces acting on a body in equilibrium · Differentiate the properties of static friction and kinetic friction · Compare the magnitude of sought quantities such as frictional force, normal force, threshold angles for sliding, acceleration, etc. · Apply Newton's 2nd law and kinematics to obtain quantitative and qualitative conclusions about the velocity and acceleration of one or more bodies, and the contact and noncontact forces acting on one or more bodies · Analyze the effect of fluid resistance on moving object	**STEM_GP12N-Ie-33** **STEM_GP12N-Ie-34** **STEM_GP12N-Ie-35** **STEM_GP12N-Ie-36** **STEM_GP12N-Ie-37**

Table 2. Lesson Outline for Board Game Packet in Force and Motion

Lesson Outline for Board Game Packet in Force and Motion 1st Quarter	**Learning Objectives**	**Time Allotment**
Pretest		1 day
Lesson Log I: (Discussion)	- Apply Newton's 1st law to obtain quantitative and qualitative conclusions about the contact and noncontact forces - Differentiate the properties of static friction and kinetic friction - Compare the magnitude of sought quantities such as frictional force, normal force, threshold angles for sliding, acceleration, etc.	2 days
Checkpoint Test		1 day
Lesson Log II: (Discussion)	- Apply Newton's 2nd law and kinematics to obtain quantitative and qualitative conclusions about the velocity and acceleration of one or more bodies, and the contact and noncontact forces acting on one or more bodies - Analyze the effect of fluid resistance on moving objects	2 days
Lesson Log II: (Activity - Game Play)	Implementation of Board Game	1 day
Post test		1 day

Table 2 provides an overview of the lesson plan for the board game in the class, and the flow of the study's implementation. The table also includes the specific learning objectives and the time allocated for each activity. This lesson plan was based on the content standards and most essential learning competencies outlined in the Department of Education's (DepEd) K-12 curriculum.

Iterative Design, Development and Validation of the Dynamic Dash board game

A game that is intended to be developed must be designed properly to achieve the objectives. Cognitive elements such as the color cards were employed to enhance the learner’s cognitive level. Social elements, including action cards, action tiles are integrated to have an interaction among the players. Lastly, immersion elements like the time and game pieces are utilized to increase learner’s involvement and interest in the developed board game. All of these game elements were implemented in the study. The research aimed to create a compelling experience that maximized learner’s engagement.

Table 3. Game Elements Incorporated

Game Elements	**Design/Implementation Strategies**
Player Tokens	Represent individual players moving across the board, encouraging engagement and competition.
Dice/Spinner	Determines how far a player moves, adding randomness and strategy to the game.
Tiles	Numbered spaces that guide player progress, with special effects that challenge or reward players.
Momentum Pass	Allows players to skip a challenge, simulating the concept of momentum in physics.
Move Forward/backward	Moves players ahead or sets them back a few spaces, introducing consequences or rewards based on their actions or performance.
Accelerate	Grants extra movement to simulate acceleration, reinforcing Newton's 2nd Law of Motion.

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Spin It	Adds an element of chance, forcing players to adjust their strategies due to unpredictable outcomes.
Rules	Ensures fair play, structured gameplay, and smooth progression through the game.
Time Logistics	Players may have a time limit to answer questions or complete their turn, maintaining a dynamic pace.

The board game is designed to engage students in learning about force and motion through an interactive and structured gameplay experience. Players take turns rolling a dice or using a spinner to determine their movement along a designated path, encountering numbered tiles and special action spaces that reinforce key physics concepts. The game includes various elements such as player tokens, challenge-based tiles, and special power-up cards like "Momentum Pass," which allows a player to skip a challenge, and "Call a Friend," which promotes collaborative learning by permitting assistance from a teammate. Additionally, "Accelerate" enables extra movement, simulating the concept of acceleration, while "Spin It" introduces an element of chance, adding excitement and unpredictability to the game.

The integration of these mechanics ensures student engagement by combining competition, strategy, and conceptual application. The dynamic nature of the game encourages active participation, problem-solving, and peer discussion, which enhances conceptual understanding of Newton’s Laws, friction, and motion principles. By incorporating gamified learning elements, the game creates an immersive educational experience that fosters both individual critical thinking and collaborative learning while maintaining a balance between challenge and enjoyment.

Table 4. Evaluation Rating Result

	Mean Rating	**Description**
Goals and Objectives		
The purpose of the game was fully explained.	4.30	Very Good
The goals and objectives of the game are clearly defined.	4.65	Very Good
The game covers key concepts of the topic.	4.40	Very Good
The game encourages students’ interaction.	5.00	Very Good
The board game helps with recalling concepts or terms.	5.00	Very Good
Average Mean	**4.67**	**Very Good**
Board Game Design		
The size of the board game is appropriate.	4.40	Very Good
The features of the board game are attractive.	4.20	Good
The materials used in the board game are durable.	4.25	Very Good
The board game is easy to use.	4.29	Very Good
Average Mean	**4.29**	**Very Good**
Components and Organization		
The mechanics of the game are clear and easily understood.	4.20	Good
The terms used are appropriate to my level of understanding.	4.30	Very Good
The game pieces such as the characters, dice and questions are appropriate and well-aligned.	4.21	Very Good
The length of time to play is reasonable.	4.44	Very Good
Average Mean	**4.29**	**Very Good**
Playability and Playfulness		
The game promotes healthy competition and cooperation.	5.00	Very Good
The rules and mechanics of the game provide players with equal conditions of fair play.	4.20	Good

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The rules of the game make it fun to play.	5.00	Very Good
Average Mean	**4.73**	**Very Good**
Usefulness		
The game is effective in introducing the topic.	4.64	Very Good
The game encourages the students to dig deeper into the subject matter.	4.55	Very Good
Playing the game is a productive use of time.	4.30	Very Good
Playing the game helps to understand the lesson.	4.30	Very Good
Average Mean	**4.44**	**Very Good**
OVERALL MEAN	**4.43**	**Very Good**

Legend: Very Good ~ 4.21-5.0 Good ~ 3.41-4.20 Fair ~ 2.61-3.40 Poor ~ 1.81-2.60 Very Poor ~ 1.0-1.80

Table 4 displays the evaluation results of the eleven valuators for the dynamic dash board game. The game was overall highly rated across all aspects, receiving a "Very Good" rating of 4.43. Its purpose, goals, and objectives were well-defined, effectively covering important concepts and encouraging student interaction while helping them remember key terms and concepts. The board design was appropriate in size and made with durable materials, though it wasn't rated as highly in terms of aesthetics. The game's ease of use also contributed to its high rating in design, which received a score of 4.29. In terms of components and organization, the game mechanics were mostly clear, though some areas could be improved. The game pieces, including characters and dice, were well-suited for the content, and the time it took to play was deemed reasonable. The playability of the game was particularly praised, receiving a very high rating of 4.73 for its promotion of healthy competition and teamwork, as well as fair and enjoyable gameplay. The game was seen as highly useful for introducing the topic and encouraging students to explore it further, effectively aiding their understanding of the lesson. Overall, the game was seen as productive and engaging, with minor room for improvement in terms of design and rule clarity.

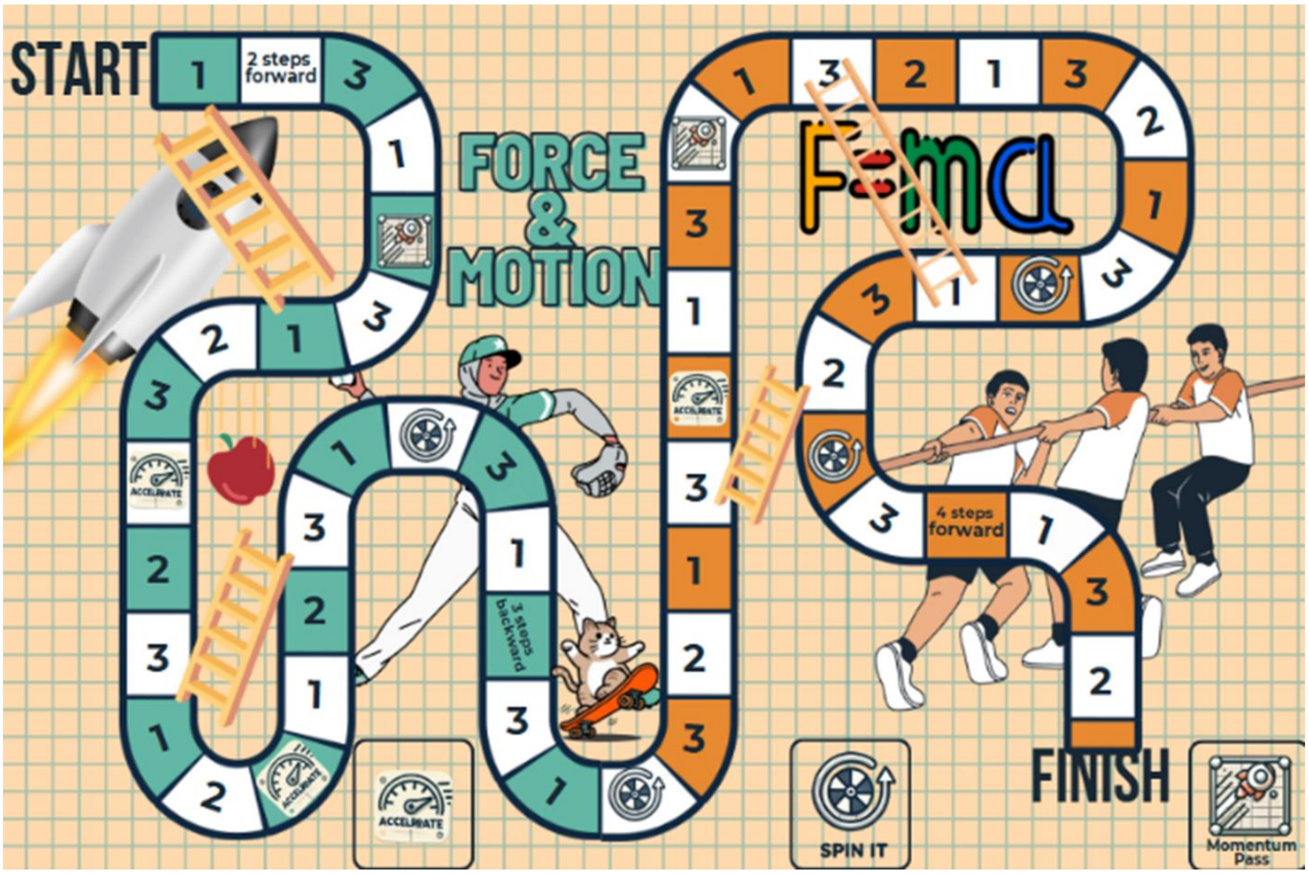

Figure 1: Final Version of the Board Game

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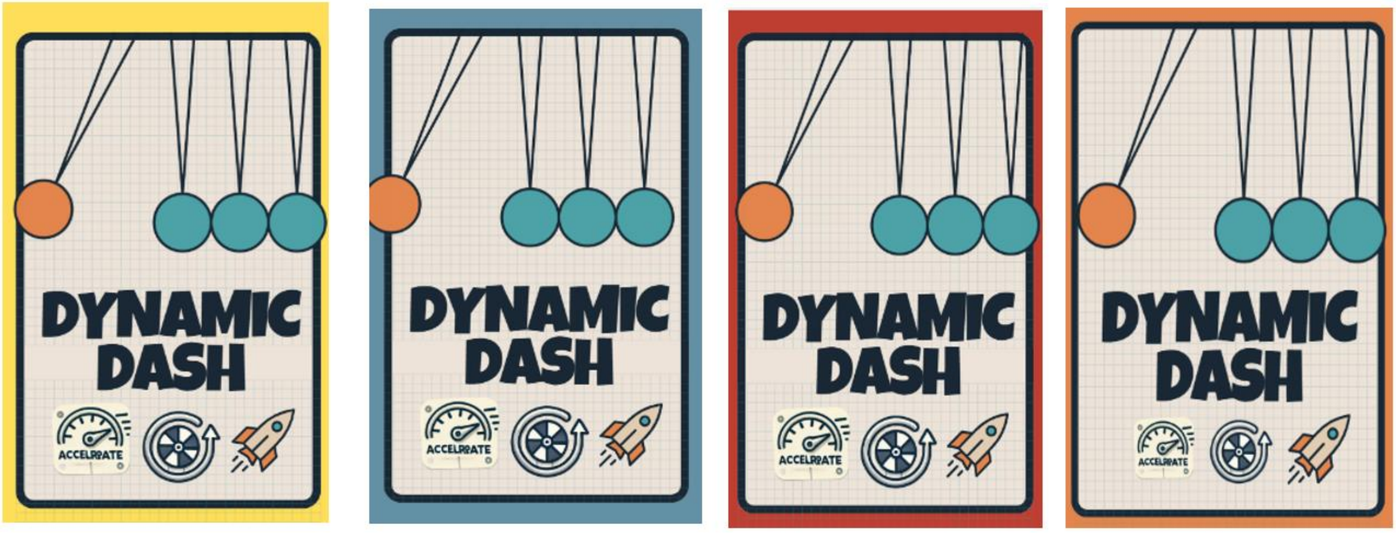

Figure 2: Front View of the Question Cards

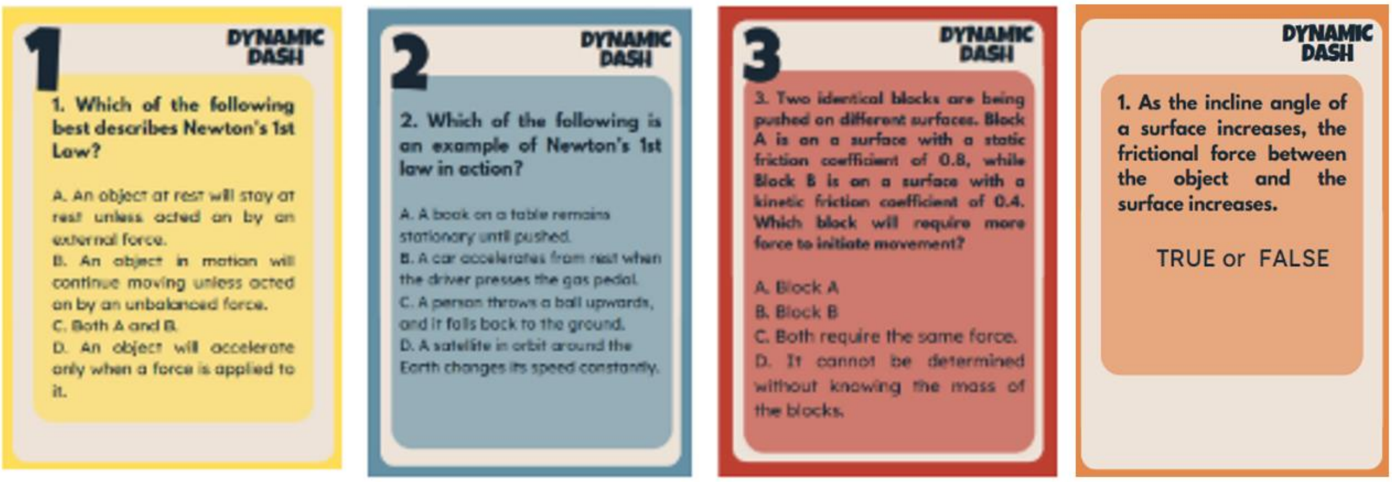

Figure 3: Back View of the Question Cards

Figure 1 shows the board game design used when a player draws a dice card. Figures 2 and 3 show the color cards. Each color card represents a different level of difficulty: yellow cards are for easy questions, blue cards for medium questions, red cards for hard questions, and orange cards for power-up questions. The color-coded cards in the board game design, representing different levels of difficulty (yellow for easy, blue for medium, red for hard, and orange for power-up questions), can be effectively used to introduce variations in game levels that cater to diverse student needs and improve adaptability. This system allows for differentiated learning, where students with varying abilities can engage with content at their appropriate skill level. For example, students who need more foundational practice can start with easier questions (yellow cards), while more advanced students can challenge themselves with harder ones (red cards). This approach supports self-paced learning, enabling students to progress at their own speed, gradually moving from basic to more complex concepts. Additionally, the power-up cards (orange) introduce an element of motivation and engagement, as students can earn advantages during the game, encouraging them to tackle more challenging tasks. By providing this range of difficulty, the game becomes more adaptable to individual learning needs, making it inclusive for all students while promoting deeper learning and personal growth. This flexibility also allows teachers to tailor the game to their classroom dynamics, offering targeted challenges to different student groups, enhancing both engagement and educational outcomes.

When a player answers a question correctly, they move ahead a certain number of steps: one step for yellow and orange cards, two steps for blue cards, and three steps for red cards. If the player is on the ladder, they must move up or down. The first player to reach the final tile of the board wins the game.

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CONCLUSION AND RECOMMENDATION

A survey was conducted to understand the challenges faced by Grade 12 STEM students and science teachers in learning and teaching the topic of Force and Motion, especially Newton's Laws and their applications. The results of this survey were important in the development and evaluation of the Dynamic Dash board game. The game received a "very good" rating from 20 science teachers and 35 STEM graduate students. This study provides a strong foundation for assessing how well the Dynamic Dash board game can help improve the academic performance of Grade 12 STEM students in Force and Motion at STI-COLLGE Iligan. The findings show that innovative learning tools like the Dynamic Dash game can help address gaps in physics education, particularly in the topic of Force and Motion. As a result, The study suggests using the Dynamic Dash game to evaluate students' understanding of Force and Motion by comparing their test scores before and after playing the game.

REFERENCES

1. Angell, C., Smith, D., & Brown, R. (2020). Challenges in understanding and applying Newton's Laws of Motion in physics education. Journal of Physics Education Research, 45(3), 245-258. http://doi.org/10.31695/JPER.2020.04503
2. Angell, C., & Brown, R. (2015). Physics Education: Bridging the Gap Between Theory and Practice. Academic Press. ISBN: 978-0-12345-678-9
3. Cardinot, Adriana & McCauley, Veronica & Fairfield, Jessamyn. (2022). Cardinot, A., McCauley, V., & Fairfield, J., (2022). Designing physics board games: a practical guide for educators. Physics Education. Available at: http://dx.doi.org/10.1088/1361-6552/ac4ac4 [OPEN ACCESS]. 57.
4. Cooke, Laquana, Lisa Dusenberry, Joy Robinson. (2020). "Gaming Design Thinking: Wicked Problems, Sufficient Solutions, and the Possibility Space of Games." Technical Communication Quarterly. https://digitalcommons.georgiasouthern.edu/writing-linguistics-facpubs/258
5. Dinscore, A., & Pho, A. (2015). Game-based learning: Developing an effective strategy for science education. Journal of Educational Research and Practice, 9(2), 45-60.
6. Dziob, S. (2018). Using board games to assess students' learning in waves, vibrations, and optics. Physics Education, 53(4), 1-12.
7. Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2016). School engagement: Potential of the concept, state of the evidence. Review of Educational Research, 74(1), 59-109. https://doi.org/10.3102/00346543074001059
8. Ji, Y., Fu, K., Venter, B. P., & Hainey, T. (2019). Ethics as a game? Towards a framework for game design. Sociology Mind, 9(3), 221-236. http://doi.org/10.4236/sm.2019.93010
9. Kothari, D. P. (2011). Energy and environmental problems facing India and their solutions for sustainable development. Souvenir from 1st International Science Congress, Indore, India, 24th-25th Dec., pp. 1-3.
10. Mae, H., & Woo, J. (2019). A conventional and digital mathematical board game design and development for use by students in learning arithmetic. Journal on Mathematics Education, 10(2), 185-200.
11. McSween, J. (2016). Learning information ethical decision making with a simulation game. Journal of Educational Technology Systems, 45(2), 223-238. http://doi.org/10.1177/0047239516646742
12. Paramanik, A., & Paramanik, R. C. (2014). Assessment of medicinal plants and environmental factors using molecular markers. International E-Publication, India, pp. 1-151. ISBN: 978-93-84648-12-1.
13. Ravi, V. (2013). A Facile Synthesis of Biologically Active Phthalimides & Its' Analogues - A Study (Doctorate Thesis). International E-Publication, India. pp 1 - 242. ISBN: 978-93-83520-15-2
14. Varala, R. (2013). A facile synthesis of biologically active phthalimides & its analogues - A study. Doctorate Thesis, International E-Publication, India, pp. 1-242. ISBN: 978-93-83520-15-2.
15. Wang, M. T., & Degol, J. L. (2017). Motivational pathways to STEM career choices: Using expectancy–value perspective. Journal of Educational Psychology, 109(3), 338-356. DOI: 1016/j.dr.2013.08.001