Development of a STEM board game on waves for grade 7 students

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Abstract. This study was conducted to develop a STEM board game on waves for Grade 7 students. The board game underwent the following stages of development: preparatory stage, game development, and expert’s assessment and validation. The study employed quantitative and qualitative research designs. After conducting two sets of pilot testing, data revealed that the categories to assess the board game were all rated excellent. Though there were suggestions for improvement, the developed board game was interesting and considered as a useful tool in demonstrating the concepts of waves and promoting STEM learning.

1. The Problem and Its Scope

1.1. Introduction

Students find physics difficult because they have to contend with different representations such as experiments, calculations, graphs, and conceptual explanations at the same time [1]. The most difficult topics for the students are those that are usually characterized as abstract, loaded with symbolic representations, lacking concrete examples and requiring a lot of mathematical manipulations, visualization or conceptualization. From previous studies, these topics are perceived difficult by students either because of the complexities of the underlying principles or because of students’ misconceptions that tend to create cognitive conflicts during learning [2].

With this problem, Physics teachers are expected to eliminate the traditional teaching practices and instead create a learning environment which provides students a project-based type of learning. Relating subjects to real-life events getting rid of the boring mathematical processes, in other words the use of special methods, would protect students from memorizing and make them participate in the lesson willingly and with pleasure [3].

Nowadays, using games to help students understand lessons are very common as a teaching method for the students. Games are said to have great potential to improve science learning in elementary, secondary, and undergraduate science classrooms. They can individualize learning to match the pace, interests, and capabilities of each particular student and contextualize learning in engaging virtual environments. As pedagogical devices, games are extremely useful because they can enliven teaching topics and are especially effective for dealing with problem solving and key concepts. Research shows that “games have a special role in building students’ self-confidence” and “they can reduce the gap between quicker and slower learners” [4].

1.2. Objective of the Study

This study aims to develop a STEM board game as a tool in demonstrating the concepts of waves and an instrument to promote STEM learning among Grade 7 students.
1.3. Scope and Limitation of the Study
This study focused on the development of a STEM board game. The developed board game serves as a supporting instructional material or assessment material for the pre-service and in-service Physics teachers. The efficiency of the board game was determined through an assessment done by the panel members, adviser, first year BSED Physics, and fourth year BSE Physics students of the College of Education, Mindanao State University - Iligan Institute of Technology.

1.4. Statement of the Problem
This study sought to answer the following questions:
1. How is the board game developed?
2. What is the level of satisfaction of playing the board game based on the following components?
   a. Mechanics of the game
   b. Physical detail
   c. Educational value
   d. Entertainment value
3. What are the comments and suggestions of the experts on the board game?

2. Related Literature and Studies
Students’ views about a course influence their understanding and learning of that course [5]. Many students think and say, “Physics is difficult”, and these students’ perception of physics as difficult subject could be a reason that students develop declining interest in physics over the course of their secondary schooling [2].

Games offer a unique structure to complement traditional teaching strategies and infuse teaching with energy, spark innovative thinking and provide diversity in teaching methods. Games make learning concepts more palatable for students and supply learners with a platform for their creative thoughts to bounce around. Games encourage creative behavior and divergent thought and are excellent ice breakers. Games will often act as learning triggers inducing lively discussion on learning concepts amongst students following game play [4].

In a study on “Board Game in Physics Classes—a Proposal for a New Method of Student Assessment”, investigating the influence of assessing students’ achievements in the form of a group board game in comparison to their former achievements and traditional tests, results showed that there is a statistically significant increase in students’ achievements in the game in comparison to their former achievements. Apart from quantitative results, the students’ enthusiastic opinions are also indicative of the social benefits of the approach, such as the development of group work skills, supporting weaker students through collaboration with others, and, in addition to these, integration of the class [6].

Another study conducted which examined the effectiveness of using board game on teaching high school physics concept, the researcher informally observed that the participants were excited to play the board game and how it could relate to physics concept. The researcher just defended how the participants can play the board game with no explanation of the content because they will discover everything by themselves when they are playing. This seemed to make the participants more excited to see what new knowledge was coming next and, also, the participants had to share information with each other [7].

A study conducted shows that board game on Physics is an effective tool for improving students’ performances. Furthermore, students play the board game without compulsion because they want to understand and learn the lesson and they are doing it with interest and enjoyment derived from the game [8].
3. Methodology

3.1. Subjects of the Study
The respondents of the study were the twenty (20) first year BSED Physics and fourth year BSE Physics students of Mindanao State University - Iligan Institute of Technology including the panel members and adviser for the validation and assessment of the board game. These respondents were deemed to have adequate understanding regarding the topic, so they were inquired to assess the developed board game. Their comments and suggestions were highly needed for the revision and improvement of the board game.

3.2. Research Design
The study utilized a combination of qualitative approach and quantitative approach in examining the data. Qualitative method was employed to examine the comments and suggestions from the panel members, adviser and BSED Physics and BSE Physics students. Quantitative method was used in analyzing data on the satisfaction level of the respondents on the game based on the different components of the rubric.

3.3. Instruments Used
This study made use of the following instruments:
1. Department of Education (DepEd) Curriculum Guide. The learning competencies for the questions used in the board game were based on the K-12 curriculum guide of the Department of Education.
2. Rubric for the Designed Board Game. It is a scoring tool that explicitly represents the performance expectations for an assignment or piece of work. In this study, the rubric used to assess the developed board game was made by the researchers and was validated by the panel members and five in-service physics teachers.

3.4. Data Gathering Procedure
The researchers first conceptualized and planned the pertinent aspects of the development of the board game. The created board game was then validated by the eight (8) in-service physics teachers including the two panel members and the adviser. After the validation and revision, the created board game was assessed by the twenty (20) first year and fourth year physics students including also the panel members and the adviser. There were two stages of pilot testing conducted. In the pilot testing, the level of satisfaction of playing the board game and the comments and suggestions were gathered. The comments and suggestions from the first pilot testing became the bases for the revision of the board game. The revised board game was then being used in the second pilot testing.

3.5. Statistical Analysis
The mean was used to determine the average rating of the level of satisfaction of the respondents on the different aspects of the board game: mechanics, physical details, educational value, and entertainment value. To interpret the students’ level of satisfaction, the following descriptions were used: 1.00-1.74 (Poor); 1.75-2.49 (Good); 2.50-3.24 (Very Good); and 3.25-4.00 (Excellent).

4. Results and Discussions

4.1. Planning
In this study, the aim was to orient students on wave phenomena in an enjoyable yet effective way which was through a board game. The board game was based on the learning competencies of Grade 7 Science Curriculum Guide of the Department of Education.
### Table 1. Learning competencies of grade 7 science.

| Content | Content standards | Performance standards | Learning competencies |
|---------|-------------------|-----------------------|-----------------------|
| Waves - transverse vs. longitudinal waves - mechanical vs. electromagnetic waves - characteristics of waves | Demonstrates understanding of waves as a carriers of energy | Develop awareness of the potential risks brought about by big waves like tsunamis | - Infers that energy, like light and sound, travels in the form of waves - Explains how waves carry energy from one place to another - Distinguishes between transverse and longitudinal waves, and mechanical and electromagnetic waves - Uses a model to demonstrate the relationship among frequency, amplitude, wavelength, and wave velocity |

The development of the game was actually inspired from an existing game called Trivial Pursuit. Some of the rules were also obtained from the said game where players are going to roll a die, answer a question before moving along the track. During the drafting of the initial design of the game board, the researchers came up with a design that looked like a 3-spoke wheel with three islands that served as the intersection point of the four tiles that go around the board. The initial design in figure 1 was a sketch with the characters drawn by the researchers.

![Figure 1. Initial board design.](image1)

4.2 Development of the Board Game

The board game consisted of four elements namely: (1) game board, (2) game pieces, (3) question cards, and (4) mechanics of the game. During the construction of the elements, it was made sure that the game was intended for Grade 7 students.

4.2.1. Board

Using the application 3D paint, better enhancements were made on the design of the board game making it more colorful and attractive. Figure 2 shows the computerized board design.

![Figure 2. Computerized board design.](image2)
4.2.2. Game Pieces
The game pieces shown in figure 3 are the ship chips with colors blue, green, and red and a die. The stand of the chips was made of a stick and a plastic bottle cap. The tokens which are the red flags were attached to small sticks and were inserted on a circular plastic caps.

Figure 3. Game Pieces

4.2.3. Question Cards
The two sets of question cards with a pirate themed design were placed in two boxes. The set of questions for the tiles was placed in a green box while the set of questions for the island was in the blue box. The question cards to be answered for the regular tiles were in a multiple choice type. For the island tiles, the question cards had hints which are jumbled letters placed below the questions. The size of each question card was 8.5 meters by 7.5 meters. Figure 4 shows the questions cards for the game.

Figure 4. Question cards.

4.2.4. Mechanics
The mechanics or rules of the game in figure 5 were all written in two pages. Each page was divided into two columns for the mechanics of the game. The design and icons found in the mechanics were made sure that they are appropriate for the topic.

Figure 5. Mechanics of the game.
4.3. Validation
The mechanics, questions, board design, and rubric were validated by the eight (8) in-service physics teachers. A total of 64 questions were validated. The game mechanics and the rubric for rating the board game were also validated.

4.3.1. Mechanics of the Game
The mechanics of the game, after being crafted, were checked by the panel members and the adviser. The in-service teachers suggested to make the statements of the mechanics uniform. They suggested to include command statements to boost the interest of the players in playing the board game. The heading “Know the Game!” was added to sound more engaging to the players.

4.3.2. Questions in the Question Cards
Researchers formulated 64 questions out of the topic needed for playing the board game. The questions were based on the supplementary materials such as books and internet sources. The questions were validated by the eight (8) in-service physics teachers. After the validation, some questions were revised and some that were not included in the learning competencies were removed.

The in-service teachers suggested to make the rubric with four columns only on the points given to arrive on terms which are not closely related to another. Initially, the highest rating was 5, but after following the suggestions of the in-service teachers, the highest rating was 4. Another column was added for the raters to write their rating on the board game.

4.4. Pilot testing
The panel members and the 20 first year and fourth year students were the respondents in the pilot testing. There were two trials made in assessing the board game. Table 2 shows the mean rating of the respondents during the first pilot testing.

| Category                  | Mean Rating | Description |
|---------------------------|-------------|-------------|
| Educational value         | 3.85        | Excellent   |
| Mechanics of the game     | 3.75        | Excellent   |
| Physical detail           | 3.65        | Excellent   |
| Entertainment value       | 3.85        | Excellent   |
| Overall                   | 3.76        | Excellent   |

Legend: 1.00-1.74 (Poor); 1.75-2.49 (Good); 2.50-3.24 (Very Good); 3.25-4.00 (Excellent)

The board game was assessed as excellent for it demonstrates comprehensive knowledge of the subject area; the mechanics were written logically, effectively and clearly; and the game pieces and game board were very creative and attractive.
Suggestions were solicited to improve the following aspects: game board, mechanics, and question cards. Common suggestions were to make the board bigger, to make the contents shorter and direct to the point, to transform the mechanics into a brochure, and to either remove the jumbled letters in the question cards or totally change the question from the one used for the regular tiles. The question cards were then revised and had only one set for the regular tile and the island tile. To address the challenge for the island tile, additional rules were made such as when the player is in the island, the opponent can steal the question given that he/she has to sacrifice his/her one token. However, if he/she fails to answer the question, the token will be given to the opponent.
Some respondents also suggested to give a separate token to every correct answer in order to give merits to those who keep on getting a correct answer but cannot get a flag. In fact according to a respondent, the game was only won through the roll of the die.
Figure 6. Revised game board.

The revised game board in figure 6 was printed in a tarpaulin and was made bigger as suggested by the respondents after saying that the game board initially was smaller. Also, the base of the board was pasted on a cardboard to make the board sturdier.

Figure 7. Revised mechanics of the game.

The mechanics of the game in figure 7 were then transformed into a brochure format. The mechanics covered one page divided into three columns. The steps were also written briefly as suggested by the respondents. The background color was also changed to blue to make the mechanics of the game more wave-like themed. The design and some icons were also modified to make it more interesting to play.

Figure 8. Revised question cards.
Some respondents commented that the question cards with jumbled letters as hints were quite easy, so they suggested to remove or change those question cards. The question cards were revised making the two sets of questions into only one set of questions. The answers were also placed at the back of the question cards since some respondents said that revealing the answers in the question card was quite difficult to show.

One respondent commented that the game can be won by luck, that is, if the player could always have the number of die landed on the island, he/she would have the greater chance of winning the game. To answer this concern, another token which was a coin for every correct answer of the player was added. Collecting five coins, which is equivalent to one flag, was the main goal of the game. The coin token had a gold color and had a “like” icon. It was placed together with the flags.

| Category          | Mean Rating | Description |
|-------------------|-------------|-------------|
| Educational value | 3.90        | Excellent   |
| Mechanics of the game | 3.80      | Excellent   |
| Physical detail   | 3.75        | Excellent   |
| Entertainment value | 3.90      | Excellent   |
| Overall           | 3.84        | Excellent   |

Table 3 shows the rating of the first year and fourth year Physics students and the panel members on the board game. After applying the suggestions of the respondents, the ratings in the different categories were higher compared to the ratings during the first pilot testing. In terms of the educational value, the initial mean rating of 3.85 increased to 3.90 during the second pilot testing. The mean rating of the mechanics of the game also increased from 3.75 to 3.80; 3.65 to 3.75 in terms of the physical detail; and 3.75 to 3.90 in terms of the entertainment value of the game.

All categories in the revised board game were rated as excellent. The educational value of the board game was excellent. Thus the game demonstrated comprehensive knowledge of the subject area. The other three categories, which are the mechanics, physical detail, and entertainment value were all rated excellent too. Thus, the respondents found the game effective and clear, creative, attractive, interesting, and enjoyable.

The respondents also gave their positive comments on the board game. Some respondents commented that the revised board game was better than the initial one. They liked the revised one because the mechanics became shorter but clearly stated. One respondent mentioned that the revised board game was better than the initial one especially in the aesthetic part, and agreed that thorough modifications were done to improve the board game.

Aside from the positive comments, the respondents also gave suggestions regarding the amelioration of the board game. They suggested to make the ship chip tenacious so it cannot be easily blown away.
For the board and chips, they suggested to have a magnetic board and game pieces. One respondent suggested that the ships can be magnetized to stay in place. For the tokens, some respondents suggested to make it a shell which may look closer to the theme of the board game. For the question cards, they suggested to have separate questions for the island and focus more on applications.

The results clearly showed that the developed board game, from a cognitive perspective, contribute to the cognitive processing of the learning content, that is how the content should be represented and how the learning mechanics should be designed to engage the learner in a way that facilitates reaching the intended cognitive outcomes.

When viewed from a motivational perspective, the ability of games to engage and motivate players is done by providing experiences that they enjoy and want to continue. The respondents saw the revised board game as outstanding in this area.

The second revision of the board game gathered more positive comments from the respondents. One respondent said that the final version of the board game was way better than the initial one especially in the aesthetic part and that a lot of thought was really put in it. Another respondent said that she really liked the game and it was very interactive.

Findings revealed that students are more likely to engage in activities that they find personally interesting and relevant. Apart from quantitative results, the students’ enthusiastic opinions are also indicative of the social benefits of the approach, such as the development of group work skills, supporting weaker students through collaboration with others, and, in addition to these, integration of the class [6].

5. Conclusion
Based on the results and findings of the study, the developed board game can be used as a useful instructional material and an excellent tool in demonstrating the concepts of waves among the Grade 7 students. Although there are some aspects of the game that needed improvement, the developed board game was easy to learn, interactive, and entertaining. The board game also helped the learners to develop their critical thinking skills. Thus, the board game can be a tool for promoting an effective STEM learning.

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