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Light Wars: An Interactive Game-Based Sim Towards A Better Understanding of Interference and Diffraction in Senior High School

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ABSTRACT

Interference and diffraction are phenomena of wave behavior discussed at senior high school level of the K-12 curriculum. Common misconceptions and low levels of understanding in this area of Physics often arise due to different factors. Due to these challenges, this study aimed to develop an engaging and educational game-based strategic intervention material called Light Wars. The content and quality of the supplementary material were evaluated by content experts in the field of Physics and students enrolled in grade 11 of the general academic strand in terms of goals and objectives, card design, components and organization, playability and playfulness, and usefulness. Based on the evaluation of the Light Wars after the utilization of the educational material, the content experts and students gave it an excellent rating and recognized it as an effective supplementary material in engaging learners, improving conceptual understanding, and concept retention. Furthermore, this study suggested that Light Wars could be utilized in other disciplines of Physical Science in grade 11 academic strands to further investigate the game's efficacy. The efficiency of the game in terms of usage between the card component and the actual hybrid game setup was also advised to be determined through comparative research.

INTRODUCTION

In the science curriculum of the Philippines, the concepts of light waves are formally introduced in the elementary grades and are developmentally discussed until the senior high school level (Department of Education, 2017). Misconceptions about light waves have the potential to prevent students' comprehension of the following concepts, especially in interference and diffraction, so they must be identified immediately (Setiaji, 2022). In the diagnostic study of Setiaji and Ermawati (2022), it was proven that most of the students involved have a lack of understanding of the Light waves Concept. Furthermore, the inability to comprehend diffraction and interference in terms of a simple wave model was one of the most significant. Interference and diffraction of light are rarely observed daily, so experiments in this field of physics must be critical. In addition, following typical classroom training, it may be said that learners have an insufficient grasp of wave optics (Cvenić et al., 2021). In addition, the study of Puspitaningtyas et al., (2021) supported this. It is stated that for senior high students to understand wave optics, structured inquiry-based learning supported by a virtual laboratory is required. As a result, students' conceptual grasp of wave optics is improved through structured inquiry-based learning supported by a virtual laboratory. It was also discovered that pupils still struggle with interference and diffraction after learning. Research studies focused on the study of physics education in terms of student conception and interpretation identified that many students had difficulties understanding conceptual comprehension. Students may be able to answer quantitative physics problems, but

they are unable to articulate straightforward conceptual issues or demonstrate conceptual knowledge of the key ideas connected to the topics (Barth-Cohen & Wittmann, 2016; Olaniyan 2022). Similarly, studies from the Physics Education Research (PER) program have revealed that wave optics is a challenging subject for learners. Prior research on college students found that many had trouble conceptualizing interference and diffraction of light. Similar issues were observed in the very few PER studies on wave optics conducted with high school or first-year university students who had not taken wave optics-related courses (Susac, 2021). In fact, "interference" and "diffraction" refer to processes that frequently create learning difficulties and are typically controlled by abstract ideas. These are two subjects where expertise is still lacking. Preliminary research showed that the preservice physics teachers (PPTs) lack of concept mastery at the study location is due to their poor enthusiasm to participate in the learning activities. Traditional approaches that are still mostly teacher-centered are used to execute learning processes. This influences the underdeveloped creative thinking abilities of (PPTs) (Saprudin, 2019). The lowest level of understanding of the concept of light occurs in indicators of knowing the definition, nature of light, and understanding the conditions for the process of reflection and diffraction of light (Yoanita and Akhlis 2015; Cari 2022). Even more, one of the fundamental concepts in physical optics is the phenomena of light interference, which offers the first experimental proof of the wavelike nature of light. Numerous investigations of learners' struggles with light interference have been done. A few researchers created how-to guides or wave visualization

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techniques to deal with these challenges and address them in the future (Dai, 2019).

Modern physics education is facing problems, especially in how to develop a better understanding of physics concepts for the students and tools that can assess the learners' understanding for possible gaps in learning the subject. (Batla et al, 2022). The study of Mulyati, Bakri, and Ambarwulan (2019) says that the textbooks in physics lack interpretation, which results in difficulties in increasing the learners' conceptual understanding of optics. The study of Vidak et al., (2020) suggests that future research must prioritize creating an approach that can effectively develop the learners' skills in using the Huygens-Fresnel principle to solve light phenomena problems such as interference of light. Senior high school students are having difficulty understanding the uses of diffraction grating as a material in physics. The researchers suggested that exposing the students to experiments would solve the problem. (Laurenty et al., 2021).

This action research aimed to develop Light Wars, a strategic intervention material (SIM) in teaching interference and diffraction. This developed strategic intervention material was evaluated by the science content experts and further utilized in one section in senior high school students enrolled in the general academic strand (GAS) to determine its effectiveness as a supplementary material. This strategic intervention material aimed to make the learning of light waves meaningful and enjoyable to the students.

METHODOLOGY

Research Design

In this study, the most appropriate research design to use was development research design, wherein the procedure aimed to create a new product that enhanced an existing one that may be announced in the initial usage

of development research. Another way to read this is that the research process uses part of the research's data to create new knowledge. The approach was employed because it intends to produce a study that addresses the study's problem (Aslichati, 2014; Rahmayati, 2021). This development research aimed to measure and determine the knowledge among the senior high school students in the lesson on interference and diffraction. Respondents were given an interactive board game as a form of assessment.

Material Development

The hybrid card and board game were designed to engage and enhance the students' conceptual understanding of wave and optics interference and diffraction concepts. The material development procedure followed the ADDIE model which stands for analysis, design, development, implementation, and evaluation (figure 1). This framework will guide you through the process of developing effective educational programs and materials for your target audience (Instructional Design, 2015; Rogayan, 2019). The analysis phase is a section where the level of conceptual understanding, depth of the topic covered, and the needs and interests of the learners were identified. In the design phase, the Light Wars game layout was developed. Additionally, the pre-test and post-test were also made in this phase. The layout of the game was crafted with the use of Canva - a free online graphic design tool. The mechanics of the game were based on Monopoly. To play the game, the participants must roll the dice before the game begins to determine the turn order. Each player is given ten lives at the start. The cards were divided into four categories: question, illustration, random, and bonus card. Each card has its own point that corresponds with the difficulty of the question represented by a lifeline. Each card that was drawn should

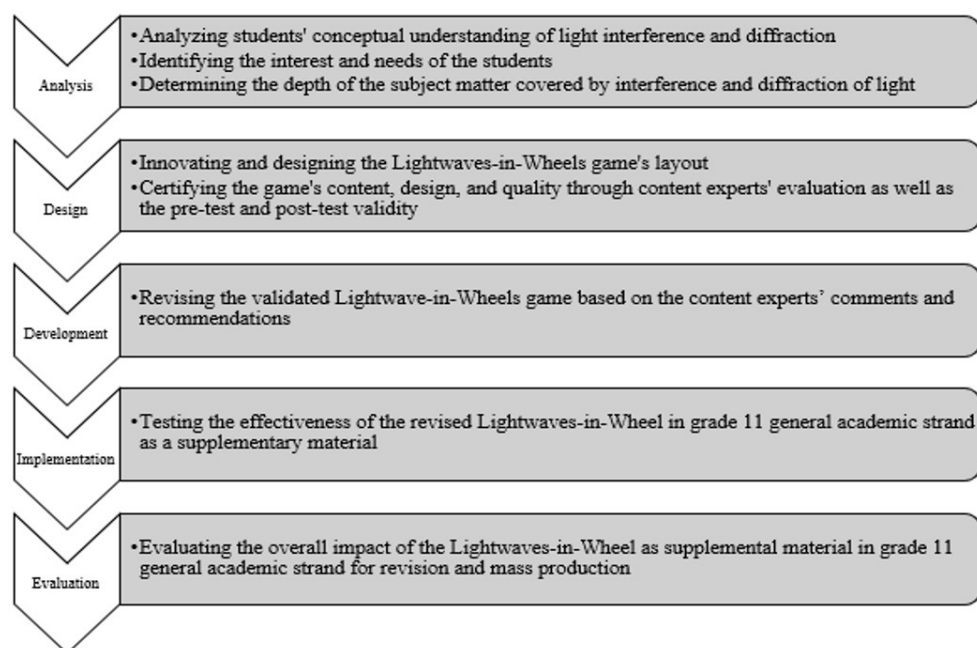


Figure 1: Material development chart using the Analysis, Design, Development, Implementation, and Evaluation model

be answered in under 30 seconds. One heart for easy, two for average, and 3 hearts for the difficult question. If the player answered the question correctly, he or she would gain life points. For example, if player 1 picked a card question card with two red hearts on it and answered the question correctly, he or she would gain two life points. If he or she answered it wrong, he or she would lose two of his life points. The player will move in accordance with the number that appeared on the dice and will take turns playing the game. In addition to the rules, penalty platforms were randomly assigned on the game board. Moreover, validation of the game's layout, questions, and quality were evaluated by content experts specialized in Physical Science as well as the validity of the test questionnaires administered to students.

In the development phase, concerning the comments and suggestions of the content experts, revisions were made to improve the game. In the implementation phase, the game was pilot tested in two groups of four to six students from one section of grade 11 in the general academic strand. In the evaluation phase, the effectiveness and engagement potential of the games were then evaluated using an evaluation form provided to the students.

Participants of the Study

Participants in this study are selected from grade 11 students of Muntinlupa National High School - Main employing convenient sampling. The participants are

divided into two groups wherein each group must have at least 4-6 members who will answer the pretest questionnaire before using the strategic intervention materials. Participants will answer the post-test questionnaire after utilizing the board game.

Research Instruments

In this study, the researcher fully utilized three instruments. (1) Evaluation tool for the hybrid card and board game "Light Wars." The tool was adapted from Gutierrez (2014) and Lawsin (2023) that aims to measure the level of experience in terms of the content and quality after the utilization of competency-based strategic intervention materials. The evaluation tool was utilized by three content expert validators and two groups of grade 11 students of Muntinlupa National High School - Main. (2) Hybrid card and board game box containing thirty cards with written questions, thirty cards containing illustrations, and thirty cards with random questions about interference and diffraction. The difficulty of the questions on the card ranges from easy to difficult level, and each card has equivalent points depending on the question's difficulty. (3) Pre-test and post-test with 15-item questions validated by experts were administered to the learners before and after implementing the strategic intervention material used to evaluate the game's efficiency in enhancing students' conceptual understanding of the topic.

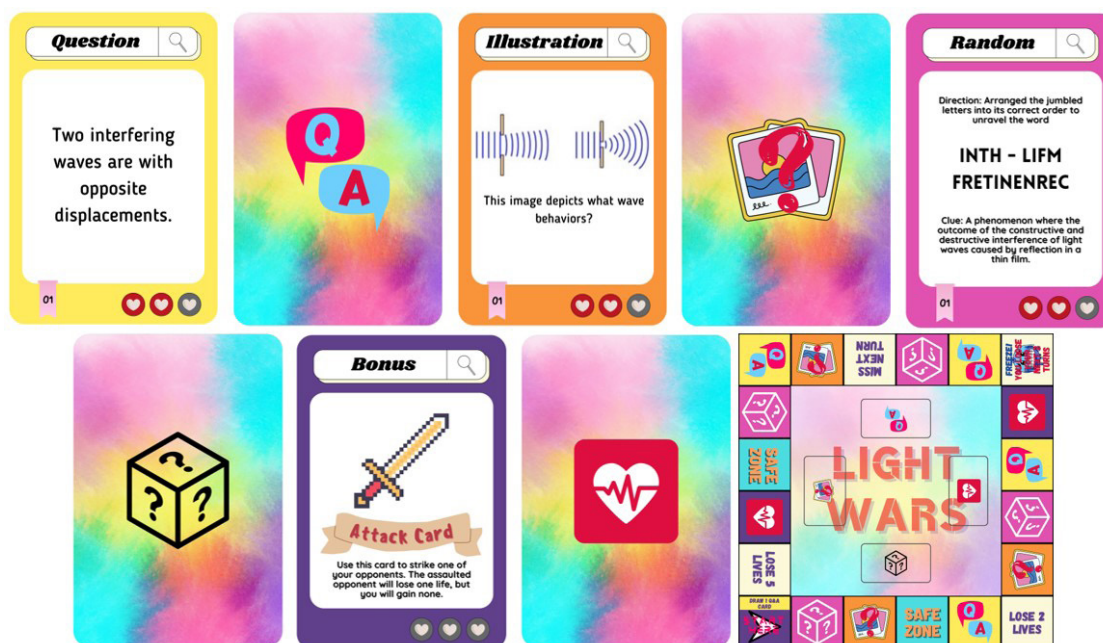


Figure 2: Sample layout of Light Wars game

Data Gathering Procedure

During the data-gathering process, there are 3 content validators that will assess the content and quality of the game. The comments and suggestions of the experts will be utilized to improve the flaws of the intervention. The participants in the study were given and asked to sign a consent form. They were also assured that the information they provided on the research instruments would be solely

for research purposes. The pretest was utilized to measure the prior knowledge of the participants in the topic, while post-tests were administered after the utilization of the intervention to measure its effectiveness. Excel was used to interpret the data from the Likert scale of the evaluation tool and was used for the statistical treatment of the data from the participant's scores in the pretest and post-test.



Figure 3: Implementation of the game Light Wars in grade 11 general academic strand

RESULTS AND DISCUSSION

Problem 1

What is the evaluation of the content-expert validators and participants regarding the content and quality of the game Light Wars?

Figure 4 and Table 1 summarize the summary of the overall descriptive evaluation of the three content-expert validators and the grade 11 participants from the general academic strand of Muntinlupa National High School - Main. The research study evaluated the five following categories regarding the effectiveness of Light of Wars: an interactive game-based strategic intervention material: (a) goals and objectives (b) card design (c) components and organization (d) playability and playfulness (e) usefulness. The first category - goals and objectives obtained an overall

excellent rating from the content expert validators and research participants with mean scores of 5.00 and 4.73 respectively. The second criterion - card design obtained an overall excellent rating from the content validators and research participants with mean scores of 5.00 and 4.90 respectively. The third category - component and organization category obtained an overall excellent rating from the content validators and research participants' mean scores of 4.73 and 4.72 respectively. The fourth category - the playability and playfulness category obtained an overall excellent rating from the content validators and research participants with a mean score of 4.83 in content-expert validators and 4.75 in students. Lastly, the usefulness category obtained an overall rating of excellent from the content validators and research

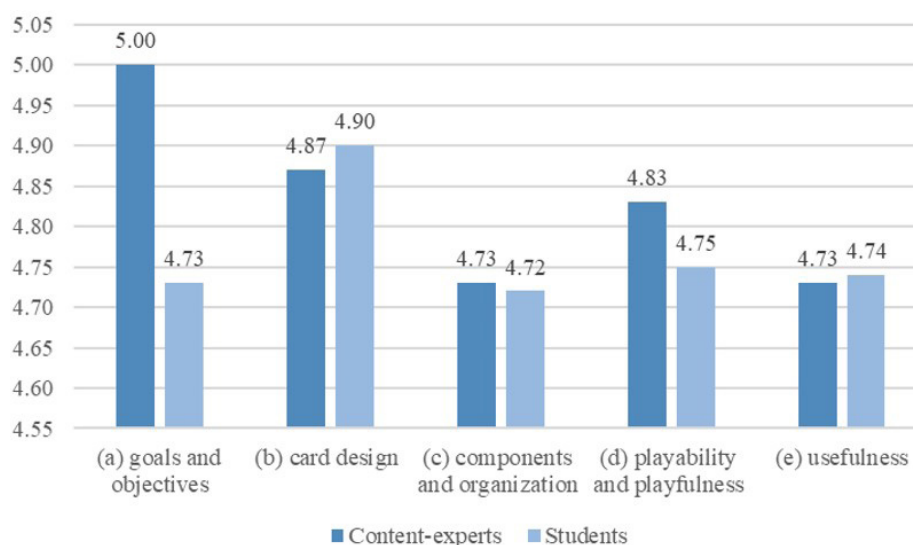


Figure 4: Descriptive evaluation of the content-experts and students towards the game Light Wars

Table 1: Descriptive evaluation of the content-experts and students towards the game Light Wars

	Items	Mean Scores	
		Content-expert Validators	Students
Goals and objectives			
1	The purpose and rationale for the game are fully explained.	5.00 (Excellent)	4.50 (Excellent)
2	The goals and objectives of the game are clearly defined.	5.00 (Excellent)	4.70 (Excellent)
3	The game was thought-provoking.	5.00 (Excellent)	4.30 (Excellent)
4	The game encouraged student interaction.	5.00 (Excellent)	5.00 (Excellent)
5	The game promoted discussion of key topics.	5.00 (Excellent)	5.00 (Excellent)
6	The card game helps with my recall of concepts/terms.	5.00 (Excellent)	4.90 (Excellent)
	Average mean	5.00 (Excellent)	4.73 (Excellent)
Card design			
7	Card size is appropriate.	5.00 (Excellent)	4.80 (Excellent)
8	Online reference of the pictures was available.	4.33 (Excellent)	4.90 (Excellent)
9	The picture printed on the card is representative of the topic.	5.00 (Excellent)	4.90 (Excellent)
10	The material used (paper) in the preparation of the cards is durable.	5.00 (Excellent)	5.00 (Excellent)
11	The deck of cards is compact and can be easily carried around.	5.00 (Excellent)	4.90 (Excellent)
	Average mean	4.87 (Excellent)	4.90 (Excellent)
Components and organization			
12	The directions were clear, concise, and easily understood.	5.00 (Excellent)	5.00 (Excellent)
13	The game emphasized key points of the topic played.	4.67 (Excellent)	4.80 (Excellent)
14	The terms used were appropriate to my level of knowledge.	5.00 (Excellent)	4.20 (Very Satisfactory)
15	The number of cards was appropriate.	4.67 (Excellent)	4.90 (Excellent)
16	The length of time required to play the game is reasonable.	4.33 (Excellent)	4.70 (Excellent)
	Average mean	4.73 (Excellent)	4.72 (Excellent)
Playability and playfulness			
17	The game provides an opportunity for healthy competition and cooperation.	5.00 (Excellent)	4.40 (Excellent)
18	The rules of the game provide players with equal conditions. for fair play.	5.00 (Excellent)	4.80 (Excellent)
19	The rules of the game pre a set of options for flexibility in making decisions when playing the game.	4.33 (Excellent)	4.80 (Excellent)
20	Playing the game was fun.	5.00 (Excellent)	5.00 (Excellent)
	Average mean	4.83 (Excellent)	4.75 (Excellent)
Usefulness			
21	The game was effective in reviewing the material.	4.67 (Excellent)	4.80 (Excellent)
22	The game encouraged the players to dig deeper into the subject matter.	4.00 (Very Satisfactory)	4.70 (Excellent)
23	Playing the game is a productive use of time.	5.00 (Excellent)	4.80 (Excellent)
24	Playing the game helped me establish better relationships. with the members of the group.	5.00 (Excellent)	4.90 (Excellent)
25	I would recommend the game to my peers.	5.00 (Excellent)	4.50 (Excellent)
	Average mean	4.73 (Excellent)	4.74 (Excellent)
	Overall mean	4.83 (Excellent)	4.77 (Excellent)

Note: 4.21-5.00 – Excellent; 3.41–4.20 – Very satisfactory; 2.61-3.40 – Satisfactory; 1.81-2.60 – Needs improvement; 1.00-1.80 – Poor

participants with a mean score of 4.73 in content-expert validators and 4.74 in students. The overall means score evaluated by the content-expert validators was 4.83 and the respondent was 4.77 respectively. The study shows that there is a significant impact of the Light War board game on the conceptual understanding of the students about interference and diffraction. Aligned with this, board games can be a motivational method for learning content and enhancing group interactions, competition,

and fun (Noda, 2019). These results proved that the Light War board games could be used as a supplementary tool to encourage and improve student learning.

Problem 2

What is the evaluation of the content-expert validators and participants in terms of the content and quality of the game Light Wars?

Table 2 shows the summary of the differences in the pre-

Table 2: Difference in the scores of Grade 11 General Academic Strand in pre-test and post-test using paired t-test

Mean Scores		p-value	Decision on null hypothesis	Remarks
Pre-test	Post-test			
4.50	6.50	0.027	Reject the null	There is a significant difference between the pre-test and post-test.
(1.72)	(1.35)			

Note: Standard deviations are in parentheses

test and post-test scores of the participants in grade 11 students from the general academic strand of Muntinlupa National High School - Main. The overall mean scores obtained in the pre-test and post-test are 4.50 and 6.50 respectively, and it was found that there is a significant difference between the pre-test and post-test mean scores wherein the p-value obtained is 0.027 which is less than the p-value threshold of 0.05 ($p < 0.05$). It can be inferred that the Light Wars game can be utilized as an alternative learning aid/material in teaching Physical Science in grade 11. These results conclude that the game is an effective intervention material to enrich the conceptual understanding of interference and diffraction. The findings of the study show synchronous results with several studies such as in the study of Yazicioglu and Çavus-Güngören (2021) wherein game-based learning in science education was an effective method to enrich students' motivation and active participation because this created an enjoyable learning environment. In this similar study, teachers were also encouraged to design and develop other game-based activities related to light and sound concepts and include them in their lessons. In the study of Putranta *et al.*, (2021), the integration of traditional game-based physics learning was found to be effective because of the contextual learning and problem-based learning models that support and maximize their abilities widely. In the study of Kuo *et al.*, (2023), it was found that in all groups of students, game-based learning and scaffolding perceived similar levels of engagement, engrossment, and total immersion.

CONCLUSIONS

Based on the findings of the study, the researchers determined that the game-based strategic intervention material was an excellent supplementary material, according to the content expert validators and research participants. This identified that Light Wars is a successful game or tool for engaging learners in a fun and active style of learning. In addition, the game encourages healthy competition among the participants and retention and

mastery of the subject matter. Playing the game takes a long time, the researchers recommend utilizing solely the cards as flashcards for recitations. To further evaluate the game's efficacy in enhancing the conceptual knowledge of the students in other Physical Science courses, it is advised to conduct a comparative study between the utilization of the card part of the game and the actual hybrid game.

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