"Spectro-Uno": Development and Evaluation of Card Game Material in Learning Light for Grade 8 Students

Cristy Fernando C. Sardinola[1], Sotero O. Malayao Jr[2], Giovanni J. Paylaga[3], Noel Lito B. Sayson[4], Dennis C. Arogancia[5], Jun Karren V. Caparoso[6]

[1,3,4,5,6]Mindanao State University-Illigan Institute of Technology/College of Education, Department of Science and Mathematics Education

[2]Andres Bonifacio Avenue, Tibanga, 9200 Iligan City, Philippines

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ABSTRACT

Science education in the Philippines faces significant challenges, particularly in physics, where students struggle with abstract concepts like light. Traditional teaching methods, often passive and resource-limited, contribute to low engagement and poor performance. This study developed and evaluated Spectro-uno, an educational card game designed to enhance Grade 8 students' understanding of light through game-based learning. The study aimed to (1) develop Spectro-uno aligned with DepEd competencies, (2) evaluate its perceived effectiveness by teachers and experts. Using the Successive Approximation Model (SAM), Spectro-Uno was iteratively developed with feedback from five in-service science teachers and five graduate students in Physics Education. Quantitative data were collected through a rating scale and qualitative data were gathered through feedback from science teachers and graduate students and a survey from grade 9 students and grade 8 science teachers. Quantitative results showed that Spectro-uno received a "Very Good" rating from science teachers and graduate students, who highlighted its ability to engage students, simplify abstract concepts, and promote active learning. The study concludes that Spectro-uno is an effective tool for teaching light-related topics and recommends its integration into the curriculum. Further research is encouraged to explore its long-term impact, emphasizing the use of pre- and post-tests to evaluate learning outcomes.

Keywords: Light, Game-based Learning (GBL), Physics Education, Card Game, Conceptual Gain

INTRODUCTION

Science education plays a pivotal role in the Philippines' educational system, aiming to cultivate critical thinking, scientific literacy, and innovation. Despite its importance, the country continues to face significant challenges in delivering quality science education, particularly in physics (Rogayan & Dollete, 2019; Moro et al., 2023). Students grapple with limited resources, overcrowded classrooms, and a lack of engaging instructional materials, which hinder their ability to fully engage with and comprehend scientific concepts (Antonowiski et al., 2017). These challenges are especially pronounced in physics, where abstract topics such as light are often perceived as difficult, leading to low learning outcomes and disinterest among students (Fayanto et al., 2019). Traditional teaching methods, characterized by rote memorization and passive learning, have been widely criticized for their inability to foster deep understanding or stimulate curiosity (Stosic, 2015). This approach often results in student disengagement, inattentiveness, and poor retention of knowledge, ultimately undermining academic achievement.

Physics education, in particular, faces unique challenges due to the abstract nature of its concepts. Studies have shown that students often struggle with topics like light, which require a strong grasp of theoretical principles and their practical applications (Kaltakci-Gurel et al., 2017). This difficulty is compounded by a lack of motivation and engagement, as students frequently perceive physics as irrelevant to their daily lives (Hake, 1998). Furthermore, the absence of hands-on activities and interactive learning tools exacerbates the problem, leaving students with fragmented and superficial understanding (McDermott & Redish, 1999). These issues

highlight the need for innovative teaching strategies that can bridge the gap between abstract concepts and real-world applications while fostering motivation and conceptual understanding.

Game-based learning has emerged as a promising strategy to address these challenges. By integrating elements of play into the learning process, educational games can enhance motivation, active participation, and conceptual understanding (Amory et al., 2016; Ge et al., 2018). Research has demonstrated that game-based learning can significantly improve students' performance in science and physics by providing immersive, interactive experiences that make abstract concepts more tangible (Clark et al., 2016). For instance, studies have shown that games designed to teach physics concepts, such as motion and energy, can lead to measurable gains in student understanding and engagement (Wouters et al., 2013). Moreover, games encourage collaboration and problem-solving, skills that are essential for scientific inquiry. While digital games and technology-based tools have shown potential, their implementation is often impractical in many Philippine schools due to limited access to electricity, internet, and technological infrastructure (Philippine Institute for Development Studies [PIDS], 2023). According to the Department of Education (DepEd), thousands of schools lack basic amenities such as electricity and potable water, exacerbating disparities in educational quality (Nyang, 2023). These constraints necessitate the exploration of low-resource, non-digital alternatives to support effective science education.

This study introduces *Spectro-uno*, an educational card game designed to teach the topic of light to Grade 8 students in resource-limited settings. Drawing on the principles of game-based learning, *Spectro-Uno* aims to actively engage students in the learning process, fostering curiosity, collaboration, and conceptual understanding. The development of *Spectro-uno* was informed by qualitative research, including iterative feedback from science teachers and graduate students specializing in Physics Education, ensuring alignment with DepEd competencies and curriculum goals. The Successive Approximation Model (SAM) was employed as an iterative design framework, allowing for continuous refinement based on user input. Quantitatively, the study evaluates the effectiveness of *Spectro-uno* by comparing the performance and engagement of students who used the card game with those taught through conventional methods. Pre- and post-tests pre- and post-tests are commonly employed to assess knowledge gains, with normalized gain scores providing a standardized measure of improvement (Hake, 1998). Qualitative data, including feedback from teachers and students, were analyzed descriptively to assess the game's usability, educational value, and alignment with learning objectives. Ge et al. (2018) used qualitative methods to demonstrate that GBL encourages active participation and peer interaction, which are critical for conceptual understanding in science education. By integrating both qualitative and quantitative approaches, this study seeks to demonstrate the potential of low-resource, game-based tool to enhance science education in underserved areas. The findings aim to provide a practical and cost-effective solution to improve learning outcomes and student motivation, contributing to the growing body of evidence supporting innovative teaching strategies in addressing educational disparities and fostering a deeper understanding of scientific concepts.

METHODS

Research Design

This study employed Research and Developmental framework with a mixed method of qualitative and quantitative support in developing the card game. The qualitative data was collected through questionnaires: Physics Motivation Questionnaire II (PMQ II) administered before and after the implementation of the card game. This was done to evaluate the impact of game-based learning on students' academic motivation. The quantitative data, gathered through evaluation and playtesting sessions during the implementation, provided measurable insights into various factors using a pretest-posttest design. For the control group, the researcher conducted a pretest and a posttest to assess their learning without any intervention. Similarly, for the experimental group, the researcher administered a pretest and a posttest to measure their knowledge acquisition of Light following the intervention.

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Research Participants

The research subjects of the study were two sections of Grade 8 students from Iligan City National High School-Main Campus (ICNHS-MAIN). The inclusion criteria for the subjects are as follows: (a) currently enrolled in Grade 8; (b) secured the consent of their parents/guardian through consent form and (c) have no medical conditions that may affect their ability to learn. Furthermore, the card game was evaluated through feedbacks and ratings from ten (10) science teachers and graduate students which guaranteed the improvement of the card game. Their role was to evaluate the design, content, and usability of the Spectro-uno card game. Additionally, 30 Grade 9 students who had previously studied the topic "Characteristics of Light" were included to provide insights into learning challenges and preferences.

Data Gathering Procedure (Successive Approximation Model)

The Successive Approximation Model (SAM), developed by Dr. Michael W. Allen in 2012, was employed to design and develop the educational card game. SAM is an iterative instructional design model emphasizing rapid prototyping, continuous improvement, and adaptability. The data collection process followed a well-organized structure, beginning with a qualitative assessment analysis that involved five (5) Grade 8 science teachers and thirty (30) Grade 9 students. Surveys were administered to both Grade 9 students, who had studied the topic "Characteristics of Light," and Grade 8 science teachers to gather insights into existing teaching methods, learning obstacles, and the particular challenges related to teaching and learning the topic of light. The process then progressed through the design and development stages, which included a quantitative assessment by validating the card game packet by the science teachers using a rating scale to evaluate the card game, allowing for systematic measurement of its effectiveness, usability, and overall quality. This structured approach ensured both qualitative insights and quantitative data were integrated to refine and assess the educational tool.

Preparation Phase

A survey was conducted in both were asked students (grade 9) who have undergone the topic Characteristics of Light and science teachers in Grade 8. They were asked about the difficulties they encountered in teaching and learning light. These findings highlighted practical classroom realities and identified opportunities where game-based learning could address existing gaps. Furthermore, the study examined the Department of Education's K-12 Curriculum Guide, particularly the Most Essential Learning Competencies (MELCs) for grade 8, to ensure alignment with curriculum standards and learning objectives to the card game content. The data gathered during this phase provided a critical foundation for designing and developing the educational card game that effectively integrates game-based learning into physics education.

Iterative Design, Development and Validation of Spectro-uno Card Game

Spectro-uno is an educational card game inspired by UNO™, carefully designed to address specific learning competencies and needs identified during the planning phase. This card game aims to teach light properties through color-coded cards categorized by difficulty (easy, moderate, difficult) using Bloom’s Taxonomy. The game includes 64 cards: question cards, answer cards, and wild cards (e.g., "scatter," "x-ray"), which simulate real-world light phenomena and enhance engagement. Questions align with the Department of Education’s Most Essential Learning Competencies (MELCs) and promote a range of cognitive skills, from recall to analysis. Players earn points based on difficulty. The inclusion of diverse card types (e.g., question cards, answer cards, and wild cards) added layers of challenge and interaction, enhancing player engagement and deepening understanding of scientific concepts (Hainey et al., 2016). Iterative feedback from graduate students and science teachers led to improvements in the card game design, color cards, mechanics, and the content. The card game was assessed using a rating scale adapted from Gutierrez (2013) and a Comments and Suggestions Sheet. All feedback and recommendations provided were incorporated into the card game. During this phase, the researcher conducted a total of four revisions to refine and improve the developed card game.

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Data Analysis

To obtain insights from the collected data, a range of statistical tools was employed during the data analysis process. Descriptive analysis was applied to evaluate the qualitative data gathered from the survey and feedback. The findings from the rating scale were analyzed using mean calculations, offering a quantitative perspective on the card game.

RESULTS AND DISCUSSIONS

Preparation Phase

This section presents the findings of the study. The qualitative data provide insights into the challenges of teaching and learning the topic of Light, while the quantitative data evaluate the effectiveness of the developed Spectro-uno card game.

Preparation Phase

The researcher conducted a survey to determine the difficulties in teaching and learning Light. This was conducted to both grade 9 students who have undergone the topic Light and grade 8 science teachers. The findings in the survey suggest that some students struggled with the complexity of the topic, while others had trouble understanding the vocabulary used. Additionally, a student mentioned sleepiness as a barrier to learning. With that, students expressed a positive attitude towards a game-like learning approach. They believe it would increase engagement, improve retention and enhance understanding. While the science teachers employed a variety of teaching methods, including visual aids, discussion, and supplementary activities. However, they encountered common challenges such as short attention spans, misconceptions, and limited class time. And they were generally positive about incorporating game-based learning into their teaching strategies. They recognized the potential of games to increase student engagement and motivation. However, they also highlighted the need to ensure accessibility for all students, especially those without access to technology.

Table 1. Summary of the Survey Conducted with Grade 8 Teachers and Grade 9 Students to Identify Challenges in Teaching and Learning Light

Questions	Student's Answer	Teacher's Answer
How was the topic taught? / How did you teach the topic?	• Through discussion and teacher showed pictures. • By explaining and giving facts of the topic. • Our adviser discussed and showed videos.	• I show them pictures and let them draw and color a rainbow. Have them discuss about color of the rainbow based on their previous knowledge. • I give supplementary activities and unlocking of difficult terms. • I discussed the topic and showed related pictures.
What were the challenges in understanding the topic? / What were the challenges you encountered in teaching the topic?	• To know the highest and lowest wavelength. • The challenge about understanding the topic is the hierarchy. • Some of the words are difficult to understand. • I can't understand because I get bored and sleepy.	• Students struggle to understand the concept and they get easily distracted and lose interest. • Insufficient time to cover the topic thoroughly due to the 45-minute class period. • Student's behavior in class, they have a short attention span. They also misunderstand the concepts, like the relationship of the properties of light.
Do you think	• Yes, more fun more	• Creating fun and interactive learning

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incorporating game in learning the topic will help? / Do you think incorporating game in teaching the topic will help?	understanding and students will remember it well. • Yes, because in game-like mode it will make the topic easier and fun. • Yes, because we can get entertaining and learn something at the same time. • For me, yes, I think I will learn a lot.	experiences is good, but the game should be appropriate to the level of students and their background. • Incorporating games into lessons can be a great way to engage students, but it's important to choose games that directly support the learning objectives. • Yes, I think this new concept of teaching might be helpful in getting the attention of the student to learn the topic.

Overall, these findings from students and teachers highlighted challenges such as complexity, technical vocabulary, boredom, short attention spans, and limited class time and suggests that a more interactive and engaging approach to teaching the topic could be beneficial. Game-based learning has been shown to increase motivation and participation by making learning more interactive and enjoyable (Hwang et al., 2012). A game-like learning mode could significantly improve student learning and satisfaction. Arboiz 2024 highlights the lack of activities and apparatus in Philippine education as a significant challenge contributing to the low performance in physics like optics which includes teaching about Light. The study of Clark et al., 2016 highlighted that games can bridge the gap between theory and practice, making abstract ideas more accessible.

Iterative Design, Development and Validation of the Spectro-uno Card Game

The game mechanics was inspired by the classic card game UNO™ with some unique features and functions that aligned with the topic Light. Both games involve players taking turns to play cards from their hands, aiming to be the first to matched of all their cards. The pile of cards was 64 in total including the wild cards, question cards, and answer cards with three (3) levels of difficulty (yellow-easy, red-moderate, blue-hard) that correspond to the points they will get (yellow-1 point. Red-2 points, blue-3 points). The mechanics of the game incorporated elements designed to enhance engagement, collaboration, and learning outcomes. Collaborative game activities are a great way of supporting the formation of groups and even friendships among players, which may encourage sustained participation (Tondello et al., 2016; Huang & Hew, 2018). It is recommended to create special or wild cards and incorporate diverse levels of difficulty when designing a card game according to Wendel, 2015. Wild cards introduce a unique twist, adding an element of surprise and strategic depth to the gameplay.

Table 2. Wild Cards and Their Function

Wild Cards	**Function**
Re-shuffle Cards:	When this wildcard is played, all the cards in the player's hand are re-shuffled, but the total number of cards remains the same. This introduces an element of unpredictability, forcing players to adapt their strategies based on their new set of cards. It also adds excitement and keeps the game dynamic, preventing players from relying too heavily on a fixed plan.
Peek at Next Group's Cards:	This wildcard allows the player to peek at two cards from the next group's hand. This strategic advantage provides insight into the opponents' potential moves, enabling the player to plan their next steps more effectively. It adds a layer of tactical thinking and encourages players to anticipate and counter their opponents' strategies.
Skip a Turn:	The "Skip" wildcard allows a player to skip their turn, effectively passing the opportunity to the next player. This can be used strategically to disrupt the flow of the game, especially if the next player is close to winning. It adds a competitive edge and forces players to think carefully

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	about when to use this card for maximum impact.
Challenges to Skip a Turn or Reverse Order (30 Seconds):	This wildcard introduces a timed challenge that players must complete within 30 seconds to either skip their turn or reverse the order of play. Challenges include activities related to the topic of light. This element adds excitement and urgency to the game, while also reinforcing learning through quick, engaging tasks. Reversing the order of play can dramatically shift the game's dynamics, giving trailing players a chance to catch up and adding an extra layer of strategy.

Moreover, timers, establish a consistent pace, preventing players from getting bogged down and ensuring smooth progress regardless of individual play styles (Silva et al., 2020). Visuals also play a crucial role; colored symbols on cards, for example, act as mnemonic devices, helping students associate specific colors with educational concepts. The inclusion of scoring adds another layer of engagement, as scoring systems provide students with clear learning goals to strive for, fostering a sense of accomplishment and healthy competition (Duggal et al., 2021). Research by Galic et al. (2023) supports this notion, highlighting that scoring in games enhances not only motivation but also engagement and fosters a competitive spirit in the learning process.

The game's mechanics were carefully designed to promote engagement, collaboration, and effective learning. The goal of the game is to be the first group to play all your cards while strategically scoring points by matching them with the cards in the center. Players must balance speed and strategy, as points are awarded based on successfully matched pairs, encouraging both quick thinking and careful planning. The rules are designed to ensure fairness and engagement: a player may play a matched pair of cards to skip their turn of drawing from the center pile, even if they do not have a match for the center card, allowing them to conserve cards strategically. However, if paired cards are not played by the end of the game, no points will be awarded, emphasizing the importance of active participation. Additionally, players can only use one wildcard per round, ensuring that these tools are used thoughtfully. The game continues until all cards are matched, giving everyone an equal opportunity to score points.

To play, the cards are shuffled, and each group is dealt 7 cards. A card is placed face-up in the center to start the game. Players take turns finding a matching card from their hand to play on the center pile. If they cannot find a match, they must draw one card from the center pile. Matched pairs are set aside for scoring, and when playing a matched card, the player must read it aloud for everyone to learn, reinforcing the educational aspect. The first group to finish their cards shouts "SPECTRO!" to declare victory, but the game continues until all cards are matched, allowing other groups to score points and determine the overall winner based on the highest score. This combination of strategic matching, active participation, and educational reinforcement makes the game both engaging and effective for learning.

Table 3. Descriptive Evaluation of the Respondents on the Developed Card Game

Items	Statement	Weighted Mean	Interpretation
Goals and Objectives	The purpose and rationale for the game are fully explained.	4.56	Very Good
	The goals and objectives of the game are clearly defined.	4.78	Very Good
	The game was thought-provoking.	4.78	Very Good
	The game encouraged student interaction.	5	Very Good
	The game promoted discussion of key topics.	5	Very Good
	The card game helps with my recall of concepts/terms.	5	Very Good

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	Average Mean	**4.85**	**Very Good**
Card Design	Card size is appropriate.	5	Very Good
	The picture printed on the card is representative of the topic.	5	Very Good
	The material used (paper) in the preparation of the cards is durable.	5	Very Good
	The deck of cards is compact and can be easily carried around.	5	Very Good
	Average Mean	**5**	**Very Good**
Components and Organization	The directions were clear, concise, and easily understood.	4.33	Very Good
	The game emphasizes key points of the topic played.	5	Very Good
	The terms used were appropriate to my level of knowledge.	5	Very Good
	The number of cards was appropriate.	4.1	Good
	The length of time required to play the game is reasonable.	4	Good
	Average Mean	**4.49**	**Very Good**
Playability and Playfulness	The game provides opportunity for healthy competition and cooperation.	4.33	Very Good
	The rules of the game provide players with equal conditions for fair play.	5	Very Good
	The rules of the game provide flexibility in decision-making.	5	Very Good
	Playing the game was fun.	5	Very Good
	Average Mean	**4.83**	**Very Good**
Usefulness	The game was effective in reviewing the material.	5	Very Good
	The game encouraged deeper exploration of the subject.	4.33	Very Good
	Playing the game is a productive use of time.	5	Very Good
	Playing the game helped build better group relationships.	5	Very Good
	I would recommend the game to my peers.	5	Very Good
	Average Mean	**4.86**	**Very Good**
Overall Mean		**4.69**	**Very Good**

The developed card game received positive feedback across all evaluated criteria, as reflected in the overall mean score of 4.69 (Very Good). The game excels in its Goals and Objectives, with a weighted mean of 4.85, demonstrating its effectiveness in clearly defining its purpose, encouraging student interaction, promoting discussion of key topics, and aiding in the recall of concepts. In terms of Card Design, the game achieved a perfect score of 5.00, indicating that the cards are appropriately sized, visually representative of the topics, durable, and portable. The Components and Organization of the game also scored highly with a rating of 4.49, with clear directions, appropriate terminology, and effective emphasis on key points. However, there is room

for improvement in the number of cards and the length of playtime, which were rated as Good rather than Very Good. The Playability and Playfulness of the game scored 4.83, highlighting its ability to foster healthy competition, ensure fair play, and provide an enjoyable experience. Finally, the game's Usefulness was rated 4.86, as it effectively reviews material, encourages deeper exploration of topics, and fosters better relationships among players. Overall, the game is a highly effective educational tool with minor areas for improvement, such as optimizing the number of cards and playtime, to further enhance its impact and engagement. Quantitative evaluation confirmed the game's effectiveness, with high ratings across all criteria with an overall mean of 4.69 which interprets as "very Good"

The feedback from science teachers and graduate students on the card game highlights its thoughtful design and educational value. Below is the summary of the feedback from the evaluators.

> *"The content of the card game is thoughtfully crafted, with themes and challenges that align well with the gameplay mechanics. It offers a good balance of complexity and accessibility, making it enjoyable for both new and experienced players."*

> *"The questions cover all the possible content knowledge from light since it also promotes not just the lower thinking skills but importantly, the higher thinking skills where students can actively create their own knowledge out of the box by applying the concept to the practical issues learned from light."*

> *"The design of the card game is engaging and visually appealing, with intuitive layouts and well-chosen colors that enhance player experience. The balance between aesthetics and functionality makes the game easy to navigate, while the creative elements add to its overall enjoyment and playability."*

"The visual elements of the cards are organized and presented in a way that clearly relates to the topic."

> *"It was simple yet properly explained everything that will happen in the game congruent to the card game design. Also, the fonts and size can be easily read and understood."*

Based on the feedback from science teachers and graduate students, the card game is a well-designed and highly effective educational tool. Its thoughtfully crafted content aligns seamlessly with gameplay mechanics, striking a perfect balance between complexity and accessibility to engage both new and experienced players. The game excels in promoting higher-order thinking skills, encouraging students to apply concepts creatively and solve real-world problems related to light. Its visually appealing design, intuitive layout, and clear instructions enhance the overall player experience, making it easy to navigate and enjoyable to use. Additionally, the game fosters collaboration, supports differentiated learning, and connects theoretical knowledge to practical applications, ensuring relevance and engagement. Overall, the card game successfully combines education, creativity, and fun, making it a valuable resource for both teaching and learning.

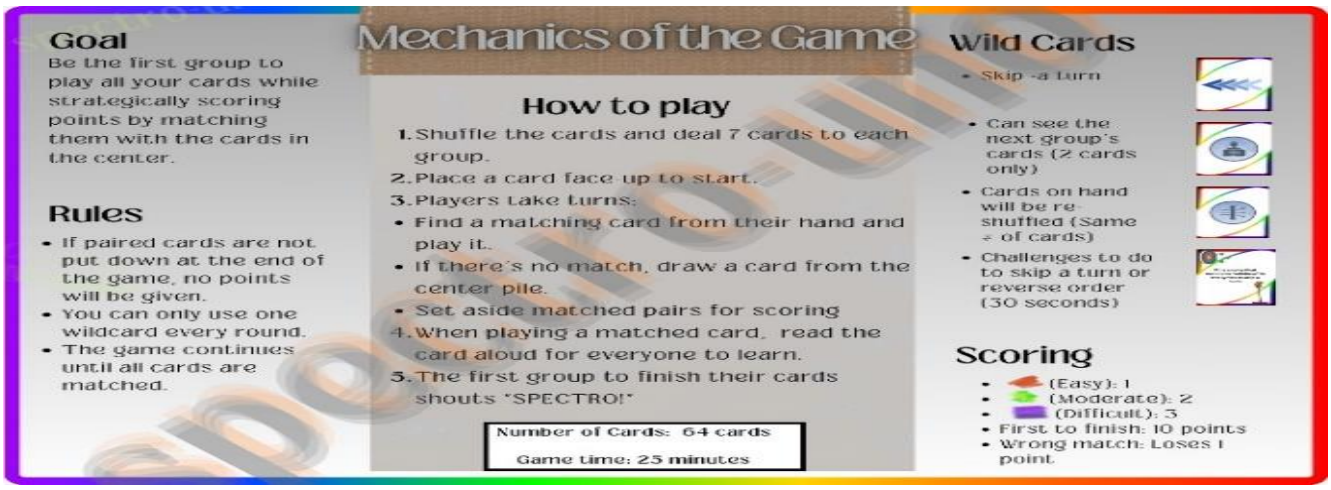

Figure 1. Mechanics of the Game Version III

Figure 2

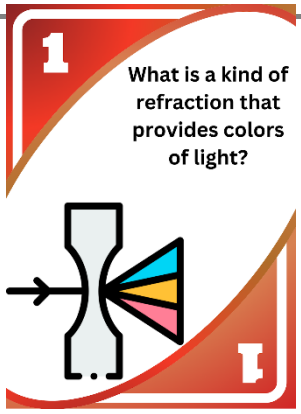

Figure 3

Figure 4

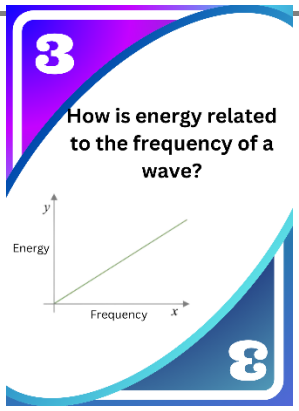

Figure 5

Figure 1 illustrates the mechanics of the game, providing a clear guide on how to play, the rules to follow and the function of the wild cards. Figure 2 shows the back side of the card, which features the game's name, "spectro-uno," designed to create a recognizable and cohesive theme. The cards themselves were categorized into three levels of difficulty: Figure 3 displays the easy card (red), worth 1 point, designed for straightforward questions; Figure 4 shows the moderate card (green), worth 2 points, offering a balanced challenge; and Figure 5 presents the difficult card (blue), worth 3 points, intended to push students' critical thinking and problem-solving skills. This tiered structure allowed players to engage with content at their own pace while encouraging progression to higher levels of difficulty. The combination of clear mechanics, visually appealing design, and scalable challenges contributed to the game's success in fostering motivation and active participation among students.

CONCLUSION AND RECOMMENDATION

The study identified significant challenges in teaching and learning the topic of Light through a survey conducted with Grade 8 learners and science teachers. These insights were instrumental in guiding the development and evaluation of the Spectro-Uno card game. The game received a “Very Good” acceptability rating from 5 in-service science teachers and 5 graduate students specializing in physics education, underscoring its potential as an effective educational tool. This research established a strong foundation for assessing the impact of the Spectro-Uno card game on improving the academic performance of Grade 8 learners in the topic of Light at Iligan City National High School, Main Campus. The findings emphasize the value of innovative learning tools like the Spectro-Uno game in addressing gaps in physics education, particularly in learning abstract concepts like Light more accessible and engaging. The study recommends using the Spectro-Uno card game to teach Light, supported by pre- and post-tests to measure its impact. The game’s framework can also be adapted for other topics, promoting interactive learning and addressing educational challenges.

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