Development and Evaluation of Plantrology Board Game: Teaching Aid to Learn Flowering Plant Physiology

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Abstract

The present work aimed to develop and evaluate the usability of Plantrology Board game to the understanding of flowering plant physiology by form five students in Terengganu, Malaysia. The ADDIE model was used as the instructional design model in developing the board game. Two content experts and 23 students were involved in evaluating the validity of the contents of the instrument and board game, as well as the reliability of the instrument. A total of 40 students participated in the real study as the respondents for the perception questionnaire. The usability questionnaire had a content validity index (CVI) of 0.86 and a reliability of $\alpha= 0.89$. Meanwhile, the board game had a CVI of 1. In terms of student's perception, the Plantrology Board Game had a high overall mean score value ($\bar{x}= 3.71$, $\sigma= 0.23$), with the design of board game, components and organizations, goals and objectives, playability, usability and satisfaction had mean value of $\bar{x}= 3.65$ ($\sigma= 0.50$), $\bar{x} = 3.84$ ($\sigma= 0.35$), $\bar{x}= 3.77$ ($\sigma= 0.43$), $\bar{x}= 3.71$ ($\sigma= 0.45$), $\bar{x}= 3.69$ ($\sigma= 0.47$) and $\bar{x}= 3.64$ ($\sigma= 0.49$), respectively. In summary, the Plantrology Board game had a high level of usability that can potentially be utilized as an effective teaching aid for both teachers and students. As an implication of the study, using games as a didactic tool in biology education can help students better understand complex concepts and ideas, while also making learning more engaging and exciting.

Keywords: Flowering Plant Physiology, Game-based learning, Plantrology Board Game, Teaching aid

Introduction

Biology are generally related to living organisms. Students may struggle to understand and apply biological concepts, and traditional lectures may not effectively represent the complexity of real-life situations or learning in practice. This is a common challenge in biology

education, as the subject often involves complex concepts and require a deep understanding of underlying principles that may be difficult to grasp through traditional teaching methods alone (Nerita & Safitri, 2023; Salleh et al., 2021; Cimer, 2012). In a preliminary survey conducted among Form 5 students in Perak, Malaysia, it was discovered that both students and teachers face challenges in the teaching and learning process of the topic of plants. Specifically, 80% of the participants reported facing difficulties in this school (unpublished data). This finding suggests that there is a need for effective teaching strategies to help students and teachers overcome these challenges and improve their understanding of the topic. According to the Secondary School Standard Curriculum (KSSM) for Form Five Biology, plant-related concepts are covered under the theme of Flowering Plant Physiology, which encompasses organization of plant tissue and growth, leaf structure and function, nutrition in plants, transport in plants, reaction in plants, sex reproduction in flowering plants, and adaptation of plants to different habitats. These topics involves a wide range of complex concepts, including plant anatomy, physiology, reproduction, and classification. Thus, it may be challenging for students to grasp, requiring a deep understanding of scientific terminology and processes. Furthermore, teachers encountered difficulties in choosing suitable teaching strategies and resources to effectively communicate plant-related concepts. The process of teaching and learning that lacks motivation can have a significant impact on students' motivation and focus in gaining knowledge (Lazowski & Hulleman, 2016). One way these challenges can be addressed is by using learning tools to complement traditional teaching methods. In addition, it is crucial to utilize a range of instructional approaches, including visual aids, demonstrations, interactive activities, and discussions, in order to accommodate diverse learning styles and improve student understanding.

The use of teaching aids, such as board games, can be very helpful for teachers in planning the teaching and learning process that implements 21st-century learning (Ezezika et al., 2023; Foster & Shah, 2020). According to Jasmi et al. (2011), incorporating teaching aids can effectively enhance student focus during the teaching and learning process (Mishra et al., 2020; Curran, 2020). In recent years, some market available biology related board games have been developed by educators to teach a variety of biology topics such as Genotype: a Mendelian genetics game, Cytosis: a cell biology game, Cellulose: a plant cell biology game, Virulence: an infectious card game, Peptide: a protein building game, Ecosystem: a family card game about animal, their habitats, and biodiversity. These games cover a range of biology topics, including botany, human biology, cell biology, and ecology. They are designed to be engaging and interactive, providing students with a fun way to learn about complex biological concepts. However, the application of board games in biology learning is still insufficient especially flowering plant physiology and most of these studies did not carry out empirical research, or lacked more dimensional analysis to further verify the effects of these board games on students' learning, such as game acceptance, user experience, and engagement. Further research is needed to investigate the effects of board games on students' learning in biology and to explore the potential of board games as a tool for teaching complex biological concepts.

Therefore, in this study, the Plantrology Board Game was developed as a suitable teaching aid based on KSSM Biology Form 5 to support 21st-century learning methods for the physiological subjects of flowering plants. This board game can help students learn about the general and floral physiology in a fun and engaging way. Furthermore, teachers can promote cooperative learning and increase students' learning enjoyment and familiarity with the subject matter.

Methodology

Research Design

The study utilized a developmental research design to create an educational board game called Plantrology Board Game, which focuses on the Physiology of Flowering Plants. The ADDIE instructional design model was used to guide the development of the board game. This research also includes evaluation studies to determine the validity, reliability, and students' perceptions on the usability of the board game. The primary objective of this research was to develop Plantrology Board Game, an educational board game to comprehend physiology of flowering plants. It was produced in accordance with the ADDIE model's five stages, which are analysis, design, development, implementation, and evaluation.

Analysis phase

During the analysis phase, a need assessment was conducted to identify problems related to difficult topics in Form 5 Biology standard curricular, as well as problems encountered during teaching and learning in the classroom. This evaluation was carried out by distributing a questionnaire to students and subject teachers. Aside from that, the potential solutions to the problems were evaluated. The results of the need analysis revealed that the topics of physiology of flowering plants was the most difficult for those studying Biology. Furthermore, it was decided to develop an educational tool in the form of a game board as a potential solution to the identified problem. This board game was designed to help students understand and master the topics of physiology of flowering plants in Form Five Biology by providing a more enjoyable learning experience. The board game objectives, and content were also determined in this phase.

Analysis phase

The design phase was implemented after the needs analysis process was completed. According to Harun and Tasir (2003), this phase describes the overall appearance, structure, teaching approaches, learning theories, types of media, and technologies that will be involved. At this phase in this study, the visual design, structure, and theoretical approach were determined and served as guidelines for the following phases. The process of creating this board game applies two types of theories, namely Jean Piaget's Cognitive Learning Theory and Constructivism Learning Theory. The application of these two theories is very important to ensure that students can build knowledge and create social skills in the classroom while playing this board game.

The Plantrology board game board is a key component of the game, and it consists of the following features (Figure 1):

- Forty spaces containing twenty-six properties: twenty-two of plant species (grouped into eight distinct colour groups) and four types of jungle.
- There also have four spaces of an extra question and also four spaces of fate for the game.
- Two spaces are for land taxes.
- Four corner squares: GO, (In) Jail/Just Visiting, Best Plants Award, and Go to Jail.
- On top of each side of spaces, there a bold line with a colour either Blue, Yellow and Red. Each of the colour are represent the level of the question.
- All of the question needs to answer by the player if they want to buy the land. If the land already bought by another player, the player must answer the question to get half prices of the land.

The board is design as a plant theme with scientific name provide in each twenty-two plants species. The board also show that the process of this game is about buy and sell of land that consists of the plant species. The Plantrology Board Game includes questions that align with KSSM Biology Form 5, which serves as a means of evaluating students' comprehension of the Physiology of Flowering Plants. The four spaces of extra question are need to be answered or they will miss the turn for two rounds. The fate spaces are about their luck either they will get a good thing such as get extra money or bad things such as a fined. The GO space is where players start the game, and they collect RM1000 every time they pass it. The Jail space is where players go when they land on the Go to Jail space or draw a Go to Jail card. Best Plants Award spaces is a space where the player can get RM200 as the prizes of the award. The objective of the game is to buy and develop properties, collect rent from opponents, and drive them into bankruptcy while remaining financially solvent and also improves their skill in Biology about Plants in theme five subtopic one to seven based on KSSM Biology Form Five.

Development phase
According to Branch (2009), the objective of development phase is to generate and validate the selected learning resources. In this phase, the actual product design process using the Canva application commenced. Questions and their corresponding answers to be included in the game were also prepared based on the learning outcomes and content standards from the Form Five Biology Curriculum Specifications for the topics of physiology of flowering plants.

Implementation phase
The implementation phase of the ADDIE model involves creating a learning environment that engages students and evaluating the usability of the product. During this phase, a pilot study was carried out to assess the reliability of the product with 23 Form Five Biology students from SMK Pengkalan TLDM in Manjung, Perak. Following the pilot study, the reliability of the questionnaire was analyzed.

Implementation phase
The final stage of the ADDIE model is the evaluation phase, which aims to evaluate the usability of the developed Plantrology Board Game through six constructs: design, component and organization, goal and objective, playability and usability, and satisfaction. This phase was conducted at Kuala Terengganu MARA Junior Science College, Terengganu, with 40 Form Five Biology students participating as respondents.

Figure 1
Plantrology Board game
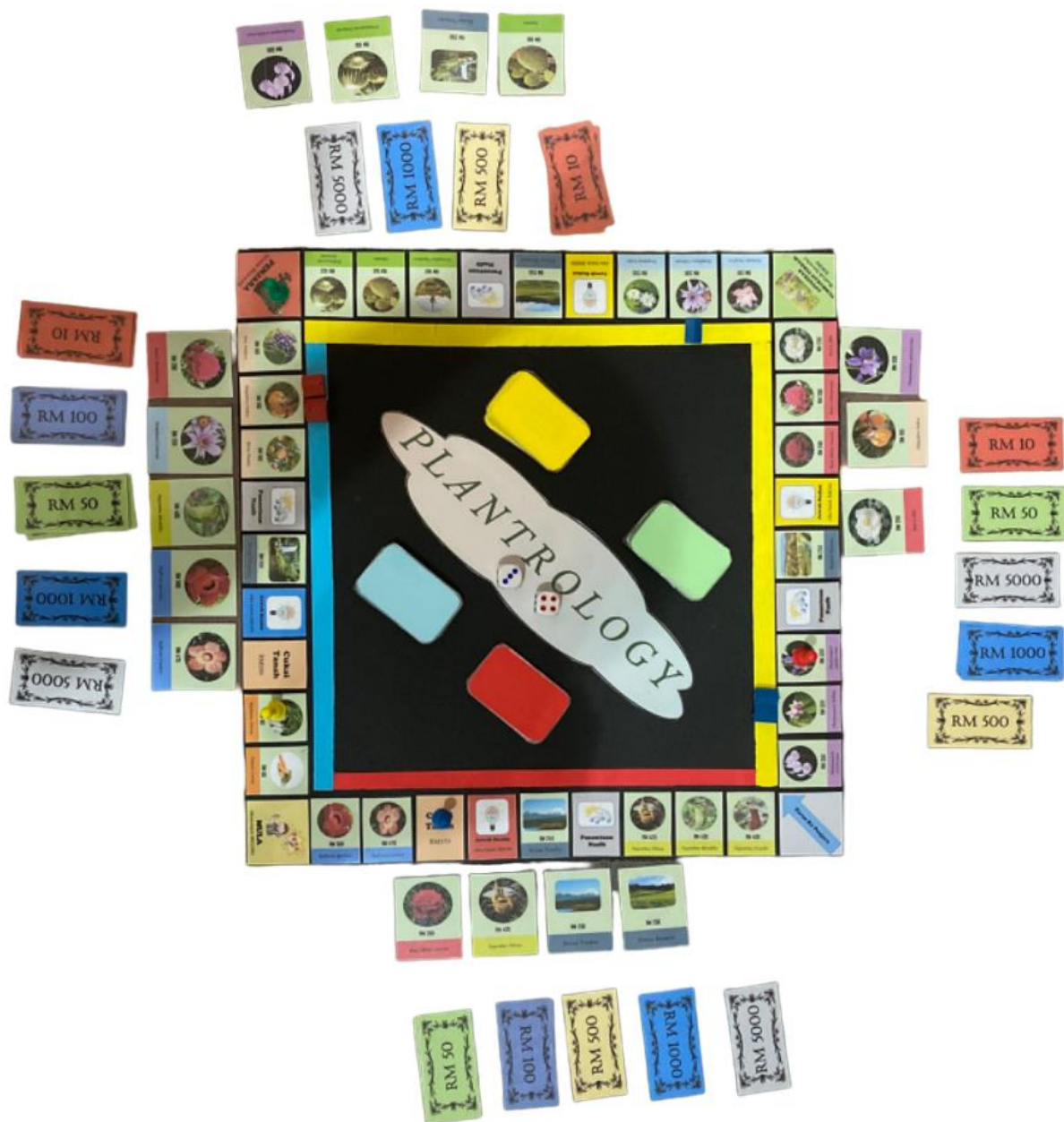
Population, Sample, and Procedure
Form 5 students in Kuala Terengganu MARA Junior Science College (MJSC-KT), Malaysia are the target demographic of this study. Respondents are chosen on the basis of the simple random sampling technique. In this study, two experts were chosen to assess the validity of the instruments and the content of the board game. To estimate the reliability of the instrument, a total of 23 form five students from SMK Pangkalan TLDM in Manjung, Perak were selected to complete the instrument usability questionnaire. Meanwhile, a group of 40 students from the MJSC-KT were selected as participant to evaluate the usability of Plantrology Board Game. Prior to commencing the research, all participants were informed about the study, requirements, and risks of participation. Consent was obtained from all

participants, and they were informed that they have the right to withdraw from the research at any stage without any penalties.

Data Collection Method
The primary data was collected through a fourth Likert Scale paper-pencil questionnaire that was administered after the teaching and learning session. Form five students were asked to rate their level of agreement with each statement on a scale of strongly disagree (1) to strongly agree (4).

Data Analysis
The questionnaire and board game underwent assessment for face and content validity using the Cohen kappa index and the Content Validity Index (CVI), respectively (Polit & Beck, 2006). The reliability of the questionnaire was analyzed using Cronbach's alpha index, while the perceptions of the board game were analyzed using mean and standard deviation. The perceptions of the Plantrology Board Game were evaluated based on six constructs: design, component and organization, goal and objective, playability, usability, and satisfaction.

Results And Discussion
Instrument and product validity, Questionnaire reliability
The Scale Content Validity Index (S-CVI) was used to evaluate the content validity of both the questionnaire and the Plantrology Board Game. Both measures resulted in an S-CVI value of 1, indicating an acceptable CVI score (Table 1). The overall reliability was reflected by the Cronbach's alpha of a 0.89, which is interpreted as highly reliable. Table 2 shows the value of Cronbach Alpha for each construct. The design, components and organisation, goals and objectives, playability, usability, and satisfaction constructs were 0.79, 0.58, 0.65, 0.76, 0.61, and 0.72, respectively.

Table 1
Content Validity of Plantrology Board Game and Questionnaire (S-CVI).

Expert Validation	S-CVI
Plantrology Board Games	$\text{S-CVI} = \frac{10}{10}$ $= 1$
Questionaire	$\text{S-CVI} = \frac{10}{10}$ $= 1$

Table 2
Value of Cronbach Alpha for Each Construct of Pilot Test of Plantrology Board Game

Construct	Number of Items	Cronbach Alpha Value, α
Design	5	0.79
Components and Organization	3	0.58
Goal and Objective	6	0.65
Playability	5	0.76
Usability	4	0.61
Satisfaction	5	0.72
	28	0.89

Evaluation of Plantrology Board Game

Board games have been shown to contribute to increasing knowledge related to each particular field and can be used as a tool to encourage learning (Zeng et al. 2020). Plantrology Board Game is a classroom tool that was developed based on the constructivist learning theory to comprehend the flowering plant physiology concept. This pedagogical approach emphasizes student communication and active participation in the assessment process. It is designed to aid in evaluating students' understanding of the topics by providing them with game structures for creating their own knowledge. The game allows students to accomplish different tasks within the game, which further adds to the learning experience.

Table 3 summarizes the perceptions of students towards the usability of Plantrology Board Game. The game's design, components and organization, goals and objectives, playability and usability received mean scores of 3.65, 3.84, 3.77, 3.71 and 3.69 respectively, with standard deviations ranging from 0.43 to 0.50. Additionally, students' satisfaction with the game resulted in a mean score of 3.64 with a standard deviation of 0.49. These results indicate that the usability of the Plantrology Board Game is significantly positive, suggesting that students perceived the game to be useful and easy to use in supporting learning.

Table 3
Descriptive evaluation of Plantrology Board Game

	Items	Min Score	Standard Deviation	Mean score level
	Design			
1.	Size of board game and question cards are suitable.	3.63	0.59	
2.	Font size and type of font used are suitable and easily read.	3.65	0.48	
3.	Language and terms used in the Plantrology Board Game are easy to understand.	3.48	0.60	
4.	Material used for Plantrology Board Game is suitable and sturdy.	3.60	0.55	
5.	Colours palate used for Plantrology Board Game is suitable	3.90	0.30	
	Average mean	**3.65**	**0.50**	**High**
	Components and Organizations			
6.	The rules of Plantrology Board Game are stated clearly and easily understandable.	3.75	0.44	
7.	Plantrology Board Game is suitable to be used to play while studying.	3.82	0.39	
8.	Plantrology Board Game focuses and emphasize on main points in the topic of Physiology of Flowering Plants.	3.95	0.22	
	Average mean	**3.84**	**0.35**	**High**

Goals and Objectives

9.	The goals of Physiology of Flowering Plants are stated clearly.	3.73	0.45	
10.	The goals and objectives of Physiology of Flowering Plants is straight-forward, accurate and clear.	3.70	0.46	
11.	Plantrology Board Game encourages interaction among students.	3.88	0.34	
12.	Plantrology Board Game encourages discussion of topics related to Physiology of Flowering Plants among students.	3.85	0.36	
13.	Plantrology Board Game helps with memorizing concepts and terms in Homeostasis and the Physiology of Flowering Plants.	3.78	0.48	
14.	The questions in Plantrology Board Game allows students to challenge their thoughts and knowledge related to the Physiology of Flowering Plants.	3.68	0.47	
	Average mean	**3.77**	**0.43**	**High**

Playability

15.	Plantrology Board Game allows players to compete and work together.	3.70	0.46	
16.	The rules of Plantrology Board Game allow players to play fairly.	3.58	0.50	
17.	Questions used in Plantrology Board Game is suitable and align with objectives of the game.	3.80	0.41	
18.	Plantrology Board Game allows me to play while studying with my friends.	3.80	0.41	
19.	Plantrology Board Game is a fun game that gives me motivation to venture in the topic of Physiology of Flowering Plants.	3.67	0.48	
	Average mean	**3.71**	**0.45**	**High**

Usability

20.	Plantrology Board Game is effective in testing myself on the topic of Physiology of Flowering Plants.	3.72	0.45	

No.	Item	Mean	SD	Level
21.	Plantrology Board Game allows players to apply their knowledge related to Physiology of Flowering Plants to their daily lives.	3.67	0.47	
22.	Plantrology Board Game allows me to master the topic of Physiology of Flowering Plants.	3.65	0.48	
23.	Plantrology Board Game is suitable to be teaching aid during and after teaching and learning sessions.	3.72	0.45	
	Average mean	**3.69**	**0.47**	**High**
	Satisfaction			
24.	I am satisfied with Plantrology Board Game as a learning material that can help in mastering the topic Physiology of Flowering Plants.	3.60	0.50	
25.	Plantrology Board Game helps me in mastering the topics in Physiology of Flowering Plants.	3.63	0.49	
26.	I will recommend Plantrology Board Game to my friends.	3.60	0.50	
27.	Plantrology Board Game is very suitable to be used as a teaching aid with friends in the classroom.	3.65	0.53	
28.	Overall, I am very satisfied with Plantrology Board Game.	3.72	0.45	
	Average mean	**3.64**	**0.49**	**High**
	Overall mean	**3.71**	**0.23**	**High**

The mean score value of the design construct is at a high level ($\bar{x}$ = 3.65, σ = 0.50), indicating that students as a whole are interested in seeing the game board, especially in terms of the use of appropriate colors. According to Adnan et al. (2015), the emphasis on image, shape, color, and text elements can make students consistently involved in learning, with the color element being particularly important as it is able to attract students. This finding is consistent with the literature on the importance of color in educational games. Studies have shown that visual aids, such as pictures, diagrams, and animations, and color can enhance the learning process and increase student engagement (Shabiralyani et al., 2015; Bobek, & Tversky, 2016; Cheung, & Ng, 2021; Cook et al., 2023).

Next, the mean score and standard deviation values of component and organization of Plantrology Board Game is also high ($\bar{x}$ = 3.84, σ = 0.35). The students really agree that this game emphasizes the main points in the theme 1 of form 5 biology: the physiology of flowering plants. In addition, the rules of the board game are clear, concise and understandable. This shows that each component and a well-organized and clear organization will make a teaching aid more interesting. This results are concordance with the findings from Cardinot & Fairfield, (2022) and Moncada &

Moncada (2014). Effective play methods should be characterized by qualitative characteristics such as having clear educational objectives and learning outcomes, identifying the skills necessary for the activities carried out, providing challenges and satisfaction through winning, have interesting colors and clear layout, contains clear and concise instructions, easy-to-understand game rules, as well as can promotes interactive player engagement.

The goal and objective construct also shows the mean score value at the high level ($\bar{x}$= 3.77, σ = 0.43). Two items in this construct obtained high mean scores ($\bar{x}$=3.88, σ =0.34 and $\bar{x}$=3.85, σ =0.36). These two items are related to the game's ability to foster interaction and encourage discussion among students (players) regarding the topic. This shows that this Plantrology Board Game strongly promotes interaction between students that is at once consistent with the theory of constructivism learning. In addition, according to Ahmad et al., (2019) said that teaching and learning sessions in the classroom should have an interactive or two-way nature in addition to actively engaging students. This is so that it is easier for them to follow and understand the lessons presented such as group work activities. The evaluation of items 3, 4, and 5 was consistent with Santos' (2019) and Botes (2022) findings, which indicated that board games are effective tool for promoting learning and engagement in the discussion topics, as well as providing student with opportunities to apply concepts they have learned.

For the playability construct also achieves the mean score value at the high level ($\bar{x}$ = 3.71, σ = 0.45). This value shows that the Plantrology Board Game clearly encourages students to play while learning with peers as well as the content of questions that perfectly meet the objectives of the game, as well as increase student's motivation to learn and mastering the topic. This result is aligned to the study by Hong et al. (2009) and Tauresia et al. (2020) who emphasized that playability of an educational game can significantly impact its effectiveness in promoting learning and engagement among students, which subsequently enables learners to be flexible, imaginative, and creative.

Next, the usability construct Plantrology Board Game received a high mean score value ($\bar{x}$= 3.69, σ = 0.47), indicating that the game is highly useful as a teaching tool for students to assess their knowledge. The respondents also recognized that the game can be conveniently used during and after the teaching and learning session in the class. In addition, they also agreed that this game provide a valuable opportunity for hands-on, experiential learning that speaks to all different types of learners in a classroom. These ratings are in concordance with the result of the study of Virvou and Katsionis (2008), Adnan et al, (2017), and Pombo and Marques (2019).

Finally, the satisfaction construct gets a value that is also at a high level ($\bar{x}$ = 3.64, σ = 0.49). This shows that the use of educational board game as teaching aid is very helpful for students to improve their understanding thus providing satisfaction to students during teaching and learning sessions. In the same vein, our findings are aligned with those of other researcher (Ignacio and Chen, 2020; Rosa-Castillo et al., 2022). In line with the results obtained in a review that evaluated the value of gamification in higher education of health science students (Arrazu and Chau, 2021), our survey respondents agreed that they would recommend the experience to their peers.

Conclusion

Plantrology Board Game was successfully developed based on the ADDIE model to improve understanding of physiology of flowering plants concept. Furthermore, the use of monopoly-based educational game as a complement teaching aid achieved a good evaluation and has educational value for Form 5 Biology students. In the nutshell, this study also contributes to the broader understanding of how board games can be utilized to encourage learning, enhance motivation of students and teachers, and improve interpersonal interactions between learners, particularly in the field of biology education. The current study is limited by the relatively small sample size of 40 form five students in Terengganu, Malaysia, which can significantly impact the validity and generalizability of the research findings. Therefore, to provide a more comprehensive understanding of students' perceptions of Plantrology Board Game, it is suggested to increase the number of research subjects to other schools from different districts and states. Additionally, future research should be conducted to identify the effectiveness of the developed board game in increasing the understanding of the topics when compared to traditional methods.

Acknowledgement

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