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Enhancing High School Students' Understanding of Plant Diversity through an Innovative and Engaging Educational Card Game

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Abstract
One of the fundamental components of science education in Thailand and other regions is the study of plant diversity. Nevertheless, students' lack of interest in this topic may be due to its overwhelming content and the perceived disconnection to their daily lives. To address this issue, an educational card game that incorporates concepts of plant taxonomy, distinctive characteristics, phylum, and several examples of local plants was developed to provide a more engaging, relevant, and conceptually appropriate approach to learning. An investigation of students' conceptual understanding before and after playing the card game, as well as their motivation towards the intrinsic value of the learning, was undertaken to assess the efficacy of the developed card game. The results of the study revealed that students' participation in the activity led to an increase in conceptual knowledge and a heightened degree of internalisation in motivation. As such, it is recommended that teachers incorporate the use of this educational card game in their curriculum to enhance students' understanding and appreciation of the topic of plant diversity.

Keywords: Card Game, Plant Diversity, Self-Determination Theory, Game-Based Learning

1. Introduction

Plant biology is an integral part of the high school biology curriculum. The subject covers various topics such as taxonomy, identification, distinctive characteristics, phylum, and examples. The inclusion of this topic in the science curriculum can pique students' interest in plants and enhance their appreciation for biodiversity. However, students' knowledge of plant biology and taxonomy is often limited, and they may find it challenging to correctly identify different plant species due to its excessive content and perceived irrelevance to daily life (Prokop et al.,

2007; Randler, 2008). Moreover, the use of technical terminology further compounds the issue, and teaching from a teacher-centered perspective can lead to disinterest and boredom among students.

Bebbington (2005) conducted a study on A-level biology students' ability to recognise and identify wildflowers. The results revealed that the majority of students could only name three or fewer plant species, and over 41% could not identify a single plant. Similarly, postgraduate students showed a lack of interest in acquiring identification skills, viewing it as the responsibility of experts. These findings are consistent with Lückmann and Menzel's (2014) study, which showed that adolescents possessed limited plant knowledge due to a lack of interest in plants. Additionally, Fanoviová and Prokop (2010) found that the majority of students lacked a favorable view of plants, despite understanding their importance in the environment.

To address this issue, a study developed an educational card game that incorporated plant taxonomy, distinctive characteristics, phylum, and local plant examples to make the subject more engaging and relevant to students. The activity led to an increase in students' conceptual knowledge and motivation, indicating its effectiveness in enhancing the learning experience (Lindemann-Matthies, 2002). Therefore, it is recommended that educators adopt innovative methods such as educational card games to make the teaching and learning of plant biology more engaging and effective.

To address the issue of learning difficulties in biology, including plant biology, science educators and teachers have experimented with various instructional strategies, such as fieldwork, laboratories, and dichotomous key identification (Lindemann-Matthies, 2002; Basey et al., 2014; Randler, 2008). For instance, Lindemann-Matthies (2002) developed an educational program called Nature on the Way to School that exposed Swiss students aged 8-16 to new species in their daily lives. However, the program's effectiveness was limited due to its duration, which took 7 weeks to complete, and the decrease in positive attitudes towards plant biology in older students. Additionally, fieldwork may only expose students to a few species and miss important technical terms required for classification (Kirchoff et al., 2014). Alternatively, Basey and colleagues (2014) investigated the efficacy of two hands-on laboratories that lasted 15 weeks in teaching plant biodiversity to undergraduates. Although both experiments improved students' cognitive and affective outcomes, it required a long duration, making them impractical for high school implementation.

Lastly, Randler (2008) compared the efficacy of dichotomous and illustration keys for animal identification instruction. The illustration key displayed an image of the respective task and symbol, while the dichotomous key began with a choice between two options. Students using picture-based illustration keys outperformed those using dichotomous keys on post-tests, indicating that text-based dichotomous keys without images produced inferior cognitive outcomes and memorisation of organisms among students. This result aligns with Stagg and Donkin's (2013) finding that dichotomous keys are less effective in promoting species identification among participants. By using effective instructional strategies, such as laboratories and illustration keys, educators and teachers can enhance students' cognitive and affective outcomes in biology, particularly in plant biology.

Card games have been found to be an effective and engaging tool in teaching various topics in science. Utilising card games in classroom instruction is practical and can greatly benefit active learners. According to Threekunprapa and Yasri (2020), card games have been employed in school education to enhance students' memorisation, comprehension, and motivation to learn. Specifically, card games can provide students with basic knowledge and technical terms, which encourage them to progress from simple to complex knowledge. Additionally, card games with engaging rules help students recall previously learned information, making the learning of biology more meaningful and attractive, especially for students overwhelmed with content. For instance, Piyawattanaviroj et al. (2019) utilised card games to teach the periodic table, while Threekunprapa and Yasri (2021) used them for computational thinking and coding. Su, Cheng, and Lin (2014) and Gutierrez (2014) utilised card games to teach human immunology and co-evolution, respectively. To demonstrate the effectiveness of card games in the teaching of biological classification, Punyasettro and Yasri (2021) designed the VERT card game to help students understand the phylogenetic classification of chordates. The card game aimed to educate students on the features of chordate classes and facilitate the construction and interpretation of evolutionary relationships using the phylogenetic tree. The efficacy of the card game was assessed by giving 109 middle school

students a pre- and post-test, revealing significant improvements in their understanding and self-efficacy for learning evolutionary biology. Moreover, students viewed the card game positively and expressed interest in using it for lesson reviews and in other topics in biology. Thus, card games are a practical and effective teaching tool that can enhance students' understanding and motivation to learn about biological classification.

In the realm of education, card games have been shown to be an effective tool for promoting student engagement and enhancing learning outcomes (Brosi & Huish, 2014). However, in the literature, there is a lack of educational card games on plant diversity that cover plant taxonomy and evolutionary characteristics. To address this gap, the present study developed an educational card game that utilises the rummy rule to promote students' understanding of plant diversity at the high school level. Specifically, the card game was designed to aid students in reviewing materials after learning about plant diversity, with a focus on promoting their remembering and understanding of the topic. While knowledge application is important in any teaching context, this study aimed to use the card game to enhance students' engagement and facilitate the development of a solid foundation for future knowledge applications. Moreover, in addition to the cognitive dimension, this study also sought to investigate the effect of the developed card game on students' attitudes towards plant taxonomy, using the self-determination framework proposed by Ryan and Deci (2000). By incorporating this framework, the study aimed to promote students' autonomous motivation and engagement in the learning process. Overall, the developed card game has the potential to be a valuable resource for high school teachers looking to enhance their students' understanding of plant diversity and taxonomy, while simultaneously promoting positive attitudes towards learning.

2. Method

2.1 The card game

The card game was developed using the rummy rule to assist students in reviewing their knowledge after studying. It has three main themes: 1) plant taxonomy and examples 2) the main characteristics of each phylum (the vascular and reproductive systems), and 3) distinguishing features. The card game is comprised of 66 cards, divided into three types: characteristics cards, example cards, and challenge cards. Examples of these cards are shown in Appendix A. The characteristics cards represent the reproductive parts of plants in four major groups and their generational alternation, using pictures and short descriptions. In each phylum, the example cards include images and plant names. Finally, there are skip, backward, and discard cards in the challenge deck.

The card game consists of two sections. The first section involves the melding of plants into the correct phylum, through which students can learn about the examples of plants in each phylum. The second section focuses on the combination of plant examples from the first section with characteristic cards. Here, students can learn about the main characteristics of plants in each phylum from the plant example cards and characteristic cards. The mission for players is to discard cards from their hands by using three possible options (as detailed in Table 1). The winner is the one who empties all cards first. For further details about the rules of the card game, please refer to Appendix B.

Table 1: Possible approaches to discard cards

1. Plants and their phylum Players are required to match a minimum of three cards of plants belonging to the same phylum from their hands and then place them face-up in front of them. For instance, mango, lotus, and coconut cards could be used as examples of melding, as they are members of the same phylum. It is important to note that players can confirm their response by checking the corresponding colour, such as pink. The picture on the right column illustrates the melding of three cards from the same phylum (anthophyte or angiosperm plants).	

2. Plants and their distinct characteristics In addition to grouping cards by phylum, players can also meld cards based on their distinctive characteristics by combining two plant example cards with at least one characteristic card from their hand and placing them face-up on the table. For example, the picture on the right column shows melding three cards that have cones as their reproductive part. The first two cards represent gymnosperm plants that have cones (the third card) as their reproductive part.	
3. Plants and their evolutionary trend Alternatively, players can meld three cards according to their evolutionary trend. They can match at least three of their characteristic cards with cards that follow the evolution trend of distinct characteristics. For example, the combination on the right column follows the trend of evolution. The first card shows the spore of a seedless vascular plant. The second card depicts a cone of naked seeds, and the third depicts a flowering plant.	

2.2 Data collection and analysis

To evaluate the efficacy of the card game, a research design was implemented to compare the learning outcomes and motivation of students before and after participating in the newly developed card game activity on plant diversity. The study utilised pre-lecture (T1), post-lecture (T2), and post-activity (T3) tests to determine changes in students' conceptual understanding of plant diversity. Furthermore, the study measured students' motivation towards learning plant diversity using the self-determination motivation questionnaire (SDT) both before and after the learning activity.

The conceptual test comprised 19 items, worth a total of 35 points, and was divided into four sections. The first section consisted of eight multiple-choice items that aimed to assess students' knowledge of nonvascular plant characteristics. The second section included five true-false items that aimed to assess students' knowledge of vascular plant characteristics. The third section comprised five matching items to test students' knowledge of plant examples at the phylum level. The final section included five multiple-choice items designed to assess students' knowledge of plant characteristics and examples from each phylum.

The student motivation questionnaire was developed based on the self-determination motivation theory (Ryan & Deci, 2000). This questionnaire was administered to investigate students' self-motivation before and after participating in the activity. The questionnaire consisted of 18 items on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). It was designed based on 6 types of self-motivation theory: amotivation, external regulation, introjected regulation, identified regulation, integrated regulation, and intrinsic regulation, each consisting of 3 items which were sorted alternately. The results obtained from the SDT questionnaire were calculated to determine the internalisation level by subtracting the summation of scores from intrinsic, integrated and identified levels (internalised levels), from the summation of scores from amotivation, external, introjected levels (externalised levels).

The research was conducted at two high schools in Bangkok, Thailand, situated in different districts of the city. A total of 102 male and female high school students who were enrolled in the science-mathematics program participated in the study. Participants were recruited using convenience sampling with ethical aspects such as voluntary participation, anonymity, and confidentiality carefully considered. The participants had prior experience with the biology material on plant taxonomy when they were in lower secondary school. However, they had not covered this subject in the level of education that is the focus of this research, which is high school.

3. Results

3.1 Student development of conceptual understanding

The data collected from the conceptual test was analysed using SPSS to investigate changes in students' learning outcomes across the three periods. The results of the analysis are presented in Table 2, which displays the mean scores and standard deviations of the students for the T1, T2, and T3 tests. The mean score for T1 was 11.70 (SD = 3.00), for T2 was 16.00 (SD = 4.45), and for T3 was 20.14 (SD = 4.94).

The Wilcoxon signed rank test was used to evaluate the statistical significance of the differences in the mean scores between the three periods. The test revealed statistically significant differences between the T1 mean and T2 mean, T2 mean and T3 mean, and T3 mean and T1 mean at a significance level of 95%. These results suggest that the participants' performance improved significantly from T1 to T2, and from T2 to T3. Furthermore, the highest mean score was observed for T3, indicating that the students' conceptual development on plant diversity was significantly enhanced after engaging in the card game activity.

Overall, the findings of the analysis demonstrate the effectiveness of the card game activity in promoting students' conceptual development on plant diversity, as evidenced by the significant improvement in their test scores across the three periods.

Table 2: The Wilcoxon signed rank test of student scores

	N	Mean	SD	Minimum	Maximum
T1	102	11.70	3.00	0.00	19.00
T2	102	16.00	4.45	8.00	26.00
T3	102	20.14	4.94	10.00	33.00

	T2 – T1	T3- T2	T3-T1
Z	-7.164[b]	-8.602[b]	-7.865[b]
Asymp. Sig. (2-tailed)	.000	.000	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

3.2 *Student improvement of motivation to learn*

After conducting the analysis on the student motivation questionnaire, the results revealed a notable increase in the level of internalisation expressed by the students from the pre-test to the post-test, as depicted in Table 3. Specifically, the average internalisation level of the students before the activity was 2.76, whereas their average internalisation level after participating in the card game increased to 4.15. The statistical difference between these two scores was determined using the Wilcoxon signed rank test, which indicated a significant improvement in the level of internalisation experienced by the students.

The findings suggest that, prior to engaging in the card game activity, the students' motivation to learn about plant taxonomy was primarily driven by external factors. However, after playing the game, they demonstrated a greater sense of intrinsic motivation, indicating that their enjoyment and interest in learning had increased. This positive shift in the students' motivation towards the topic has important implications for their future academic performance and engagement in biology, as well as their overall attitudes towards learning in general.

Table 3: The Wilcoxon signed rank test of self-determination

	N	Mean	SD	Minimum	Maximum
Pre	102	2.76	6.58	-8	33
Post	102	4.15	7.51	-13	34

	Pre-Post
Z	-2.622[b]
Asymp. Sig. (2-tailed)	.009

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

4. Discussion

The initial performance of students on the pre-lecture examination (T1) suggests that they had limited knowledge of plant diversity (Lückmann & Menzel, 2014). This is a common issue that affects a broad age range of school students and may also be prevalent among the general population. Even among biology students who are expected to master this type of material, underdeveloped ability to identify plant taxonomic groups has been reported (Bebbington, 2005). Despite this, there was an overall statistical increase in students' comprehension of the assessed topic. As expected, students performed better on tests after listening to the lecture (T2), as lectures can effectively impart broad and deep knowledge in a short amount of time. However, the post-activity test yielded the highest mean score (T3), indicating that playing the card game can reinforce students' understanding to an even greater degree. This finding highlights the effectiveness of the card game in teaching plant diversity. Although it is possible that students may not directly use the card game as an instructional tool to generate their understanding from scratch, it serves as an effective revision tool that students can use after completing their formal studies. By making sense of the rules and attempting to win the competition, implementing the card game in this manner assists students in reviewing their lessons and broadening their comprehension.

This positive result can be attributed to the card game's ability to provide students with background knowledge and conceptual understanding of plant taxonomy and its primary characteristics related to evolution. By focusing on the function of the card game, it offers students a unique opportunity to learn and review the subject matter. By arranging three cards into groups, students can learn about the primary characteristics of plants, including the alternation of generations, the reproductive parts of plants, and the vascular system. When students correctly match the example of a plant to its characteristics, they gain knowledge of the various characteristics of each plant. The results of this study validate this assumption, as test scores indicate that playing the card game helps students improve and review their knowledge in this area. In addition, one of the card game's rules is matching plants to their phylum. Students must know which phylum each plant belongs to and match at least three cards together. By doing so, students can gain knowledge of plant examples from various phyla. Although this study involves matching three cards based on their corresponding colours, it is possible to argue that students can gain familiarity with the game beyond just relying on colour matching through repeated gameplay. Moreover, comparing students' scores before and after the card game reveals that students' scores improved in this section after playing the card game. In sum, this study demonstrates that the card game effectively promotes students' understanding and engagement in learning plant diversity. By providing a fun and interactive way to review the material, the card game can supplement traditional teaching methods and enhance students' comprehension of the subject matter.

Based on the findings of this study, it appears that educational card games can be an effective way to improve students' conceptual understanding of a topic. This result is consistent with other studies that have employed educational card games to address learning difficulties in various contexts (Gibson et al., 2015; Gutierrez, 2014;

Punyasettro & Yasri, 2021; Stagg & Donkin, 2013; Su et al., 2014). However, some doubts have been raised regarding whether the improvement in students' test scores is due solely to the card games themselves or to the influence of the teacher's instruction during the lecture. This study sought to address these doubts by highlighting the positive impact of both the lecture and the card game activity on students' conceptual understanding. It is important for teachers to recognise the limitations of their role in this learning package. While it may be tempting to provide clear explanations to students, in this case, the explanation is given only to a certain degree, enough for students to proceed with the game. Some parts require students to learn from the game itself. Therefore, the teacher's explanation in this study focused only on technical terms and key features relevant to the game, such as the name of each phylum, the main characteristics, the alternation of generations, and some examples. Students must construct their understanding by applying these key concepts to examples presented on the cards and practicing with multiple repetitions to become more familiar with and remember the material. This study, therefore, highlights the potential of educational card games as an effective teaching tool to enhance conceptual understanding. Moreover, it underscores the importance of the teacher's role in guiding students through this process, striking a balance between providing necessary explanations and allowing students to construct their understanding through active participation.

Turning to the discussion about student motivation to learn, after playing the card game, the majority of students appeared to be more internalised to intrinsic motivation, indicating that they enjoyed learning more. This indicates that the activity could assist students in transitioning from externally-driven factors of learning, externalisation, which have dominated their learning since the beginning, to intrinsic motivation. This is a positive indicator of learning in any context. To shift from extrinsically controlled motivation, SDT suggests that the extrinsic level of motivation can be changed to a higher level of internalisation through a well-designed educational innovation and teachers' facilitation of student learning (Christopher & Ryan, 2009). In this study, the teacher's role consisted of introducing the essential content and the learning activity, as well as acting as a facilitator to provide students with feedback to reduce student anxiety regarding the academic content of the game. Students playing the card game felt more challenged and less pressured as a result. In addition, the design of the card game and the activity contribute to this favourable outcome. This is due to the fact that the competition's rules are designed to provide students with a challenging environment in which to compete.

Focusing on possible suggestions for further studies, first and foremost, the content of this card game contains information about plant diversity focusing on the characteristics of plants within each phylum. Therefore, this content necessitates that students know plant terminology and their characteristics. Based on this, it is recommended that the lecture section and teacher explanation are important for the implementation of the card game activity. This is because teaching in an active learning classroom does not mean that teachers should do nothing. Several studies start the activities with instructors who explain the introduction of content before students start playing the game. In addition, to make this type of educational innovation applicable to learning contexts, it is essential to provide students with local plants that they are familiar with, so that they can see the value and apply it in their lives. Furthermore, this concept can be applied to other biology topics that require students to comprehend the relationship between technical terms. Last but not least, rummy games have been made appear online in various platforms for recreational purposes. This physical game can be converted into an online activity that educates and entertains student players in a more engaging manner and can be used in a blended learning environment as suggested by the existing literature (Maleesut et al., 2019; Seangdeang & Yasri, 2019).

To finish up the discussion, we would like to point out conceptual and methodological challenges in this study. First, conceptual limitations of this card game revolve around its content which is excessive for students to learn in their limited time. This is because plant examples in some phyla contain multiple species. Therefore, to play in the allotted time, the card game could not provide students with all examples of plants, but could only serve students with familiar species or local plants. Second, time constraints represent a methodological limitation in this study. Due to the excessively brief high school period, students only had fifty minutes to play the card game as a result of the study's design. Thus, students could only play it for two or three rounds at most. This would have been more efficient if they had more time to play and discuss with their classmates. In addition, although the student participants could play the game with no major difficulties, the rule is quite complicated, perhaps for other

groups of learners who are not familiar with the rummy rule. Students probably need more time to get into the rule and play efficiently.

5. Conclusion

Plant diversity is an important topic for high school students because it is a fundamental concept that can be applied to other disciplines, including botany, ecology, and the environment. However, the majority of students viewed this subject as difficult and were less interested in plant diversity. This is because of the volume of material and students' perception that it has no relevance to their daily lives. This study, therefore, developed a card game to assist students in learning and reviewing this subject matter. According to the effectiveness of card games, the participating students had poor prior knowledge about plant diversity, but after studying in the lecture section, their knowledge improved statistically, and the card game could even help them retain this knowledge and improve their understanding even further. This indicates that to implement the card game, the teacher must still introduce the topic to the students and serve as a facilitator when the students play card games. The developed card game should be used after students have knowledge about technical terms and what technical terms refer to. This will enable students to play the card game with greater fluency and benefit. Also, this study revealed that students' motivation to learn about plant diversity was becoming significantly more internalised, demonstrating a significant change in intrinsic motivation. The change in students' motivation resulted from the teacher's instruction and the card game they played. This implies that the design of a card game-based learning activity should combine teaching and playing to be effective.

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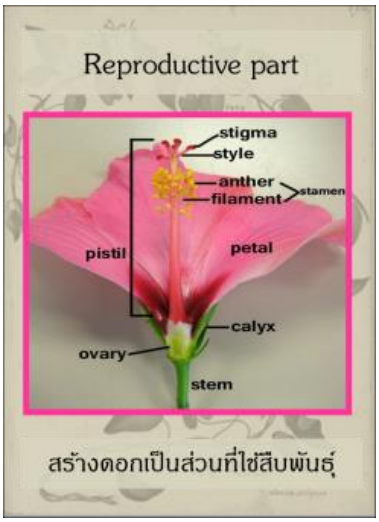
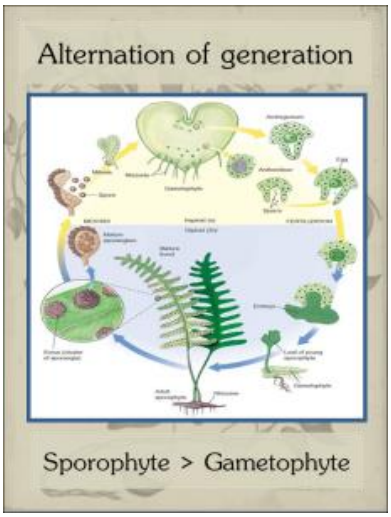
Appendix A: The cards

Characteristics cards





Plant example cards

Appendix B: The rule of the card game

Each round can have between two and seven players. The roles of the players are as follows:

1. After all players have been dealt a hand of playing cards, the player to the dealer's left will begin pulling cards. A player must add one card from the top of the stock pile or the top of the discard pile to their hand in order to draw a card. The discard pile is revealed, letting players to see who they will get in beforehand. If a player chooses to draw from the stock, they will not see the card until after they have committed to accepting it. The card is added to the player's hand without being shown to the other players.
2. If a player has a valid group or sequence in their hand, he or she may meld the cards by placing one of these combinations face up in front of him/her. A player cannot create multiple combinations in a single turn. Melding is optional; players are not required to do so. To lay down cards is optional as well. If desired, a player may add cards to groups or sequences they or others have previously melded. A player may discard any number of cards during his or her turn.
3. A player must discard one card from their hand at the end of their turn and place it on top of the discard pile. If a player begins their turn by taking the top card from the discard pile, they may not complete their turn by discarding the same card, leaving the discard pile untouched. A player may retrieve a card from the discard pile and then discard it on a subsequent round. If a player draws a card from the stock, he or she may choose to discard it within the same round. If there are no more cards in the stock pile and the next player chooses not to accept the discard, the discard pile is flipped without shuffling to produce a new stock, and play continues.
4. At least three cards must meet the criterion for a player to be able to add a card from his hand to an existing set on the table. In the game, challenge cards play specific roles. For the skip card, the player may play it to skip that turn without drawing additional cards. In the case of backward cards, the player to the right of the player who discards the backward card must play the following turn, and the game then returns to the left. The player may discard and play a card along with other cards that correspond to the given description of plant vascular.
5. A player wins a hand by melding, laying off, or discarding all of his or her cards. Using one of these strategies to eliminate a player's final card is known as going out.