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MODERN EDUCATION
(IJMOE)**www.gaexcellence.com/ijmoe**ADVANCED HAPPY FAMILY: AN EDUCATIONAL CARD
GAME FOR LEARNING SI PREFIXES, SYMBOLS AND
VALUES**

Intan Syaffinazzilla Zaine^{1*}, Marina Mokhtar², Mohd Bukhari Md Yunus³, Tuan Mustapha Yeh⁴

¹Department of Applied Sciences, Universiti Teknologi MARA, Cawangan Pulau Pinang, Kampus Permatang Pauh, 13500, Permatang Pauh, Pulau Pinang, Malaysia

 intan.zaine@uitm.edu.my

 <https://orcid.org/0009-0007-9137-5869>

²Department of Applied Sciences, Universiti Teknologi MARA, Cawangan Pulau Pinang, Kampus Permatang Pauh, 13500, Permatang Pauh, Pulau Pinang, Malaysia

 mmarina@uitm.edu.my

 <https://orcid.org/0000-0001-5809-1935>

³Department of Applied Sciences, Universiti Teknologi MARA, Cawangan Pulau Pinang, Kampus Permatang Pauh, 13500, Permatang Pauh, Pulau Pinang, Malaysia

 bukhari.myunus@uitm.edu.my

 <https://orcid.org/0009-0007-1868-9255>

⁴Micron Memory Malaysian Sdn. Bhd., Batu Kawan, Pulau Pinang, Malaysia

 tbintuanyeh@micron.com

 <https://orcid.org/0009-0000-6886-724X>

*Corresponding Author

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Abstract:

Learning SI prefixes requires students to remember the relationship between the prefix, its symbol and its corresponding value. This can be difficult when students need to remember the three representations at the same time. This study examined the use of Advanced Happy Family: Prefix Edition, a card game developed to help students learn SI prefixes through a family-collection activity. A classroom-based pre-test-post-test design was used with 19 Pre-Diploma Science (STEM C) students at Universiti Teknologi MARA (UiTM) Cawangan Pulau Pinang. The students completed the same 18-mark matching test before and after playing the game. A post-intervention survey was also given to obtain their perceptions of the game. The mean score increased from 11.84/18 (65.8%) in the pre-test to 14.37/18 (79.8%) in the post-test. The larger improvement was found in the symbol-to-value association, which increased from 38.0% to 62.6%, compared with 93.6% to 97.1% for the prefix-to-symbol association. The item-level results also showed improvement in several symbol-to-value associations, particularly pico, centi and milli. The survey results showed positive responses for Social Experience (98.9%), Competition (97.8%) and Playfulness (96.7%),

followed by Immersion (88.9%) and Challenge (86.7%). The findings suggest that Advanced Happy Family: Prefix Edition can be used as an interactive classroom activity to help students practise the relationship between SI prefix names, symbols and values.

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Keyword:

Educational Card Game; Game-based Learning; Gamification; SI prefixes; STEM Education



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Introduction

The International System of Units (SI) is an international system of measurement that allows for the consistent communication of technical information and measurements across countries (Bureau International des Poids et Mesures, 2026). It is necessary for SI prefixes to be a part of the system, as they are decimal multiples and submultiples of SI units with standardised names and symbols (Newell & Tiesinga, 2019). Tera (T), mega (M), kilo (k), milli (m), micro (μ), nano (n), and pico (p) represent powers of ten ranging from 10^{12} to 10^{-12} . The importance of SI prefixes was further highlighted by the 27th General Conference on Weights and Measures (CGPM) in 2022, which extended the range of SI prefixes with the addition of ronna, quetta, ronto and quecto (Bureau International des Poids et Mesures, 2022).

Learning SI prefixes requires students to establish associations between three related representations: the prefix name, its symbol, and its corresponding multiplying factor (Ürek, 2020). These associations are not always straightforward because prefix symbols may differ in case and may not provide an intuitive indication of their numerical values (Oğuzhan Dinçer & Osmanoglu, 2018; Sokolowski, 2015). For instance, mega is represented by an uppercase M and corresponds to 10^6 , whereas milli is represented by a lowercase m and corresponds to 10^{-3} . Similarly, micro (μ), nano (n), and pico (p) represent 10^{-6} , 10^{-9} and 10^{-12} , respectively. The standardised relationship among prefix names, symbols and powers of ten is specified in the SI Brochure and related SI guidance (Thompson & Taylor, 2008).

For students with limited prior exposure to science, learning such foundational representations may be challenging, particularly when the information is mainly acquired through memorisation (Oğuzhan Dinçer & Osmanoglu, 2018). This issue is relevant in introductory

science programmes where students need to develop foundational knowledge within a relatively short period before progressing to more complex scientific concepts (Raje, 2019). Providing opportunities for active engagement and repeated interaction with learning content may therefore be beneficial for supporting the acquisition and retention of foundational STEM knowledge (Freeman et al., 2014). A recent meta-analytic review of digital educational games in STEM education reports positive effects on learning outcomes, supporting the potential of game-based approaches as a complementary strategy in STEM learning (Gui et al., 2023).

Game-based learning can also provide an alternative learning environment in which students interact with learning content while participating in structured gameplay (Vlachopoulos & Makri, 2017). In physics instruction, board games have been termed as a possibly engaging and motivational tool when the rules of the game are carefully designed to be related to the learning objectives (Cardinot et al., 2022). The results of the systematic review of game-based learning in STEM education also highlighted that the learning objectives and the game design should be well aligned, and that the game design should be seen as a pedagogical tool and not merely a tool for entertainment (Videnovik et al., 2023). The results of this study imply that, when educational concepts and content are repeated in the rules and objectives of games, the use of such games can be especially helpful (Lameras et al., 2016).

In response to this learning need, Advanced Happy Family: Prefix Edition was developed as an educational card game by adapting the classic Happy Family card-game concept to the learning of SI prefixes (TzuFen et al., 2014). The game consists of ten SI prefix families, with each family represented by three related cards: the prefix name, its symbol, and its corresponding power of ten. For example, the Tera family is completed by collecting the Tera, T, and 10^{12} cards. Players compete to collect complete families, while action cards introduce additional strategic elements into the gameplay. The design therefore requires students to repeatedly associate the three representations of an SI prefix while interacting with peers during gameplay (Chen et al., 2012). The present study aimed to examine changes in students' performance in identifying SI prefix symbols and corresponding powers of ten following participation in Advanced Happy Family: Prefix Edition. The study involved 19 Pre-Diploma Science (STEM C) students in a classroom try-out, with students' learning performance evaluated using pre-test and post-test assessments.

Methodology

Research Design and Participants

This study employed a classroom-based pre-test–post-test design to examine changes in students' understanding of SI prefixes following the implementation of Advanced Happy Family: Prefix Edition, an educational card game (Liu & Chen, 2013). The participants comprised 19 Semester 1 students enrolled in the Pre-Diploma Science (STEM C) programme at Universiti Teknologi MARA (UiTM) Cawangan Pulau Pinang. Ethical approval for the study was obtained from the UiTM Research Ethics Committee under reference number REC/03/2026 (ST/MR/60).

Development of Advanced Happy Family: Prefix Edition

Advanced Happy Family: Prefix Edition was developed by adapting the concept of the classic Happy Family card game to the learning of SI prefixes. The aim of the game is to introduce

students to the relationship between three different representations of an SI prefix: the prefix name, the prefix symbol, and the corresponding power of ten (Gutierrez & Eric, 2014).

There are 10 SI prefix families in the game. Each family contains 3 cards with the prefix, its symbol, and the value of the prefix. For instance, the nano family is a family of cards including a nano card, an n card and a 10^{-9} card. A player must collect all three of these cards to make a family. Action cards are also included with the family cards to add extra strategy to the game. Figure 1 shows the components of the Advanced Happy Family: Prefix Edition card game.

The design for the cards was developed using Canva and then submitted for printing. The cards were designed in a standard gaming-card size for easier handling during play.

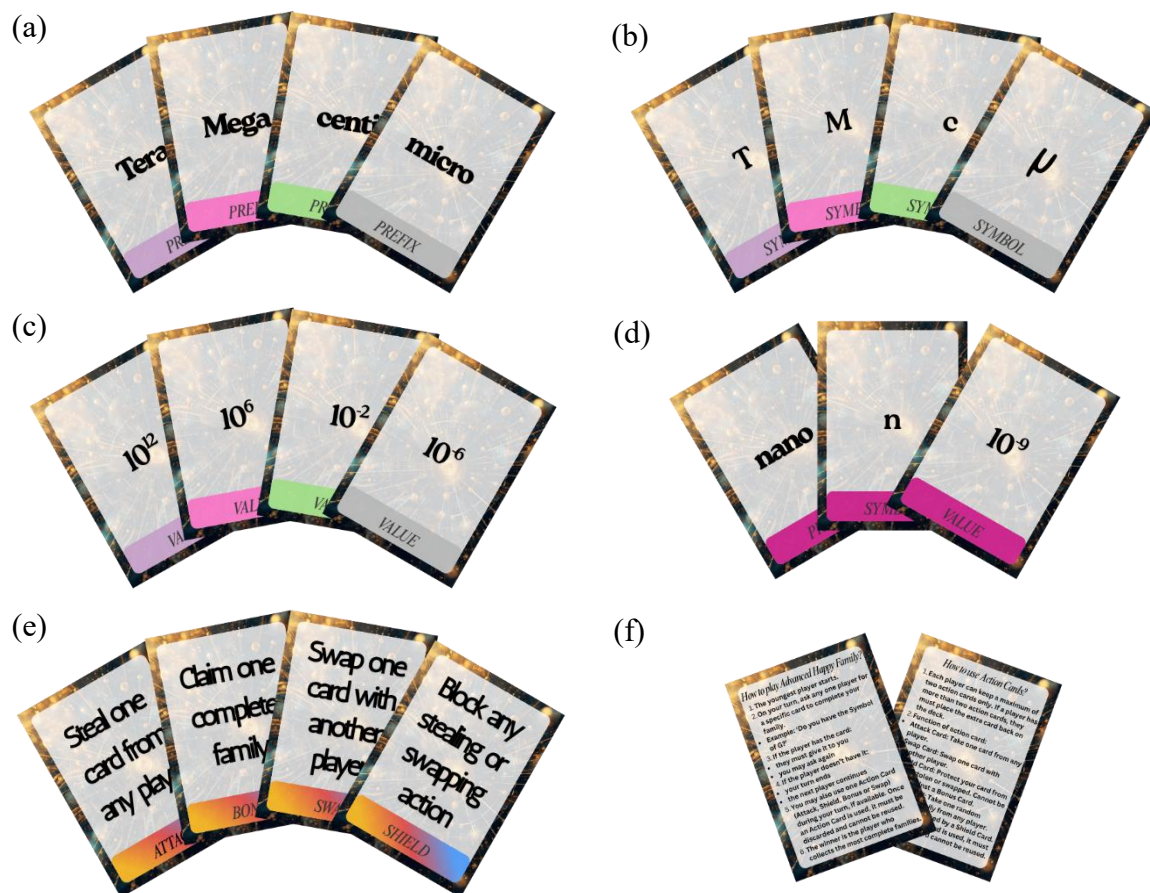


Figure 1: Components Of The Advanced Happy Family: Prefix Edition Card Game: (A) Selected Prefix Cards, (B) Corresponding Symbol Cards, (C) Corresponding Value Cards, (D) Nano Family Cards, (E) Action Cards, And (F) Instruction Cards

Intervention Procedure

The intervention took place after the first classroom teaching of the topic of the SI system. The topic was first introduced through regular classroom instruction. A pre-test was then administered after several weeks to determine the students' prior knowledge of SI prefixes.

The pre-test was administered individually using a matching format. After the students completed the pre-test, the instructor went over the SI prefix topic, focusing especially on the

relationships between the name, the symbol and the power of ten of each prefix. Students were then presented with the rules and procedures of Advanced Happy Family: Prefix Edition.

The physical cards were issued, and the game was played in the classroom. Students were given an opportunity to familiarise themselves with the game and collect cards to complete the SI prefix families. Each round lasted approximately 15–20 minutes, with the player who collected the most completed prefix families being declared the winner. The students played several rounds before proceeding to the post-test, which was the same assessment used for the pre-test. Upon completion of the post-test, the students were asked to complete the post-intervention questionnaire regarding their experience and perceptions of the card-game activity.

Pre-test and Post-test Instrument

The pre-test and post-test used an identical matching assessment with a maximum score of 18 marks. The assessment covers 10 SI prefixes, with each prefix associated with its corresponding symbol and power of ten. The prefixes were presented in a random order to reduce the likelihood of students relying on a fixed sequence when completing the matching task.

The assessment consists of two types of associations: prefix-to-symbol and symbol-to-value. For the prefix-to-symbol association, students were required to match each prefix with its corresponding symbol. For the symbol-to-value association, students were required to match the corresponding symbol with its power of ten. One prefix was provided as an example in the assessment, in which deci was matched with the symbol d and the symbol d was matched with its corresponding value, 10^{-1} . Each correct association was awarded one mark.

Although 10 SI prefixes were included in the assessment, the maximum score was 18 because the assessment measures 18 scored matching associations, comprising nine prefix-to-symbol associations and nine symbol-to-value associations. The deci example was not included in the scored items. Thus, the total possible score was 18 marks.

For example, if a student correctly matches micro with μ but incorrectly matches μ with 10^{-9} , the student receives one mark for the correct prefix-to-symbol association and no mark for the incorrect symbol-to-value association.

The identical assessment was administered before and after the intervention to allow comparison of students' performance following participation in the card-game activity.

Student Perception Survey

A post-intervention survey was administered to obtain students' perceptions of the gameful experience during the card-game activity. The questionnaire was adapted from selected dimensions of the Gameful Experience Questionnaire (GAMEFULQUEST) developed by Högberg et al. (2019), which measures different dimensions of gameful experience. In the original instrument, responses were recorded using a seven-point Likert scale ranging from strongly disagree to strongly agree. For the present study, the response format was adapted to a Yes/No format to make the questionnaire simpler and more suitable for the participating Pre-Diploma Science (STEM C) students.

The adapted questionnaire consists of five dimensions: Playfulness, Immersion, Social Experience, Challenge, and Competition, with five items representing each dimension, resulting in 25 items in total. The items were used to describe students' perceptions of their experience during the card-game activity. The dimension of Playfulness emphasised enjoyment, exploration, curiosity and creativity among students in the activity. The Immersion dimension studied how much attention was paid to the game and how involved the students were in it. The Social Experience dimension involved interaction, support, collaboration, and social involvement with classmates. The Challenge dimension targeted the students' sense of challenge, considering the critical thinking and challenging work that was inherent in the game. Lastly, the Competition dimension focused on students' competitive experience and motivation to win during the game.

A total of 19 students were involved in the card-game intervention and pre-test/post-test evaluation, but 18 students completed the post-intervention survey. Consequently, only 18 responses were used for the survey analysis.

Data Analysis

Descriptive statistics such as the minimum score, maximum score, range, mean score, median score, mode score, standard deviation, and Pearson's skewness were used to analyse the pre-test and post-test scores. The statistics used reflected the overall distribution and change in students' performance before and after the intervention.

In addition, an item-level analysis was conducted by determining the number and percentage of students who answered each matching item correctly in the pre-test and post-test. The item analysis was then broken down into two parts, namely prefix-to-symbol association and symbol-to-value association. The analysis was employed to find the SI prefixes and associations that were easier or harder for students before and after the intervention.

The number and percentage of Yes responses for each of the 25 items were computed for the post-intervention survey. The findings were then consolidated based on the five dimensions of the questionnaire: Playfulness, Immersion, Social Experience, Challenge, and Competition. This analysis was employed to describe students' perceived experience of Advanced Happy Family: Prefix Edition.

Results and Discussion

Overall Pre-test and Post-test Performance

The descriptive statistics of the students' pre-test and post-test scores are shown in Table 1. The mean score increased from 11.84/18 (65.8%) in the pre-test to 14.37/18 (79.8%) in the post-test, representing an increase of 2.53 marks or 14.0 percentage points. The median score rose from 11 to 15, and the mode rose from 11 to 16. The overall results show an improvement in students' performance after the implementation of Advanced Happy Family: Prefix Edition. The score distribution also changed after the intervention. The Pearson's skewness value changed from 0.30 in the pre-test to -2.09 in the post-test. The slightly positive skewness in the pre-test indicates that the scores were distributed towards the lower-to-middle range, whereas the negative skewness in the post-test indicates that more students obtained scores towards the

higher end of the scale. The standard deviation decreased slightly from 2.48 to 2.34, indicating a slightly narrower distribution of scores in the post-test.

The improvement in the mean, media, and mode suggests that the increase in performance was reflected across the score distribution rather than being attributable only to a small number of high-performing students. In particular, the increase in the median from 11 to 15 indicates that the middle position of the score distribution shifted considerably towards higher scores after the intervention. Similarly, the change in mode from 11 to 16 indicates that the most frequently obtained score increased substantially.

The shift from positive to negative skewness provides further evidence of this change in the distribution. The negative skewness in the post-test was mainly due to more students obtaining higher scores, while fewer students remained at the lower end of the score range. This pattern is mirrored in the frequency distribution, where six students achieved a score of 16 in the post-test, and just two students gained a score of 16 in the pre-test.

Table 1: Descriptive Statistics of Pre-test and Post-test Scores

Statistic	Pre-test	Post-test
Maximum score	18	18
Minimum score	9	9
Mean	11.84	14.37
Percentage of full mark	65.8%	79.8%
Median	11	15
Mode	11	16
Standard deviation	2.48	2.34
Pearson's skewness	0.30	-2.09

However, these results should be viewed with some caution due to the small number of students, which was 19 in total, and the same pre-test and post-test were used. Some improvements might have been observed due to familiarity with the assessment (Roediger & Karpicke, 2006).

Prefix-to-Symbol and Symbol-to-Value Associations

The assessment was structured into two sections: prefix-to-symbol association and symbol-to-value association, to be able to identify the specific parts of the SI prefix knowledge that changed after the intervention. The results are shown in Table 2.

Table 2: Performance According to Type of Association

Association	Full mark	Pre-test mean	Pre-test %	Post-test mean	Post-test %	Increase
Prefix → Symbol	9	8.42	93.6	8.74	97.1	+3.5 pp
Symbol → Value	9	3.42	38.0	5.63	62.6	+24.6 pp
Overall	18	11.84	65.8	14.37	79.8	+14.0 pp

pp = percentage points

In both test conditions, students' performance on the prefix-to-symbol association was considerably higher than their performance on the symbol-to-value association. The mean score for the prefix-to-symbol association rose from 8.42/9 (93.6%) to 8.74/9 (97.1%). The mean score for the symbol-to-value association, however, rose from 3.42/9 (38.0%) to 5.63/9 (62.6%), a gain of 24.6 percentage points.

This distinction is important because it shows where students experienced more difficulty. Students seemed to have fairly good prior knowledge of the relationship between a prefix and its symbol, but they had much more trouble linking the symbol to the power of ten of the number that it represented. The larger improvement in this area may be related to the numerical values component included in the card game.

The findings could be related to the structure of Advanced Happy Family: Prefix Edition. To complete a family, students had to be able to link three representations, not just remember an isolated prefix. For instance, when students completed the tera family, they had to think of Tera, T, and 10^{12} as being associated. The same three-card layout was used for all the SI prefix families. In the game, students were repeatedly exposed to these related representations as they worked on their families. This repeated association might have contributed to strengthening the relationship between the SI symbols and the numerical values.

More importantly, the component that was the most difficult in the pre-test showed the greatest improvement in the post-test. This implies that the card game might have offered more learning aids to the weaker aspect of students' SI prefix knowledge, the association between symbols and powers of ten.

Item-Level Analysis of SI Prefix Associations

For this purpose, an item-level analysis of the specific SI prefix associations that students found more difficult was carried out, as well as a comparison of the changes after the intervention. The results are presented in Table 3.

The difference between the two types of associations is further illustrated by the item-level analysis. In the prefix-to-symbol associations, most items had good pre-test performance, and six of the nine had 100% accuracy. The lowest pre-test performance was observed for micro $\rightarrow \mu$ and milli $\rightarrow m$, both at 73.7%. Both increased to 89.5% in the post-test.

A different pattern was observed for symbol-to-value associations. The lowest pre-test performance was recorded for $p \rightarrow 10^{-12}$, with only 15.8% of students answering correctly. This was followed by $m \rightarrow 10^{-3}$ (21.1%) and $\mu \rightarrow 10^{-6}$ (26.3%). Following the intervention, the largest improvement was observed for $p \rightarrow 10^{-12}$, which increased from 15.8% to 78.9%, representing a gain of 63.2 percentage points. The associations $c \rightarrow 10^{-2}$ and $m \rightarrow 10^{-3}$ also showed substantial gains of 47.4 percentage points each.

The relatively high pre-test scores for prefix-to-symbol associations suggest that students were already familiar with many SI prefix symbols. Consequently, there was limited room for improvement for several items. In contrast, the lower pre-test performance for symbol-to-value associations indicates that recalling the numerical magnitude represented by a symbol was more challenging. The substantial gains observed for pico, centi and milli therefore provide

further support for the overall finding that the symbol-to-value association was the component that benefited most from the intervention.

The kilo $\rightarrow 10^3$ item showed a small decrease from 68.4% to 63.2%. This difference represents only one student in a sample of 19 and should therefore not be interpreted as evidence of a general decline in understanding. Similarly, the unchanged performance for M $\rightarrow 10^6$ indicates that the intervention did not result in improvement for every individual association. Nevertheless, the overall pattern across the items was positive, particularly for the symbol-to-value component.

Table 3: Percentage of Students Correctly Identifying Each SI Prefix Association

Prefix/symbol/value		Pre-test (%)	Post-test (%)	Gain (pp)
Prefix $\rightarrow$ Symbol	Tera $\rightarrow$ T	100	100	0
	pico $\rightarrow$ p	100	100	0
	Mega $\rightarrow$ M	100	100	0
	centi $\rightarrow$ c	100	100	0
	micro $\rightarrow$	73.7	89.5	+15.8
	Giga $\rightarrow$ G	100	100	0
	kilo $\rightarrow$ k	100	100	0
	milli $\rightarrow$ m	73.7	89.5	+15.8
	nano $\rightarrow$ n	94.7	94.7	0
Symbol $\rightarrow$ Value	T $\rightarrow 10^{12}$	36.8	78.9	+42.1
	p $\rightarrow 10^{-12}$	15.8	78.9	+63.2
	M $\rightarrow 10^6$	42.1	42.1	0
	c $\rightarrow 10^{-2}$	36.8	84.2	+47.4
	μ $\rightarrow 10^{-6}$	26.3	52.6	+26.3
	G $\rightarrow 10^9$	31.6	42.1	+10.5
	k $\rightarrow 10^3$	68.4	63.2	-5.3
	m $\rightarrow 10^{-3}$	21.1	68.4	+47.4
	n $\rightarrow 10^{-9}$	36.8	52.6	+15.8

Students' Perceptions of the Card Game

A post-intervention survey was administered to examine students' perceptions of Advanced Happy Family: Prefix Edition. A total of 18 students completed the survey. The questionnaire had 25 Yes/No questions which focused on five dimensions: Playfulness, Immersion, Social Experience, Challenge, and Competition, whereby each dimension is comprised of five items. The overall results of the survey indicated very positive perceptions in all five dimensions. The most common affirmative responses (in percentages) were for Social Experience (98.9%), Competition (97.8%) and Playfulness (96.7%). High percentages of Yes responses were also seen for Immersion (88.9%) and Challenge (86.7%).

There were several items that received 100% Yes answers at the item level. Four of the five Social Experience items received Yes responses from all 18 students, while the remaining item received 17 Yes responses. All five Competition items picked up very positive responses, with four items receiving a 100% Yes response. Three items had a 100% Yes response for Playfulness, and 17 and 16 Yes responses, respectively, for the remaining two items.

Table 4: Students' perceptions of Advanced Happy Family: Prefix Edition

Dimension	Number of Yes responses	Total responses	Yes (%)
Social experience	89	90	98.9
Competition	88	90	97.8
Playfulness	87	90	96.7
Immersion	80	90	88.9
Challenge	78	90	86.7

The lowest individual answer was for the Immersion item, which asked if the game led students to leave their everyday concerns behind during play: 14 of 18 students (77.8%) gave an answer of Yes. Several Challenge and Immersion items received 15 Yes responses (83.3%). Nevertheless, these responses still indicate that a substantial majority of students perceived positive experiences during the game.

The physical card-game activity created opportunities for interaction among students, as indicated by the highest response for Social Experience (Bahurudin Setambah et al., 2024) which is 98.9%. Students had to interact with their classmates while playing the game and trying to complete their SI prefix families (Sousa et al., 2023). This strong feedback might be due to the physical interaction with classmates when playing a card game.

The competitive element was also well perceived by the students, as evidenced by the high response obtained in Competition (97.8%). The aim of completing families and winning was clear in the game. The competitive aspect might have motivated students to stay focused and engaged during the activity (Sailer & Homner, 2020).

Likewise, Playfulness received a positive response from 96.7% of the students, indicating that the activity was generally a fun and engaging experience (Höyng, 2022). This is important for the design of the innovation, as the learning task was not just posed as a classic matching task but was integrated into a game. As players flipped through the cards and collected the matching ones, it may have added to the 'fun' of the learning.

The Immersion (88.9%) and Challenge (86.7%) had lower percentages than the other dimensions, but they were still very high (Bui et al., 2020). The results show that most students gave positive responses for these two dimensions. The lower response for Challenge could be due to students' individual perceptions of challenge, as the students also had varying levels of prior knowledge of the SI prefixes (Admiraal et al., 2011).

Limitations and Future Studies

This study has some limitations. First, the number of participants was small, involving only 19 Pre-Diploma Science (STEM C) students. Therefore, the results may not represent students from other groups or larger populations. The participants were also only a portion of the students involved in the classroom implementation. The findings should therefore be considered within the classroom setting of this study.

Second, the study used a single-group pre-test–post-test design and did not include a control group. The increase in the post-test score may not be due to the card game alone. The students were also given a re-explanation of the SI prefix topic before playing the game, and the same

test was used for both the pre-test and post-test. These factors may have contributed to the improvement in the post-test results. Therefore, the results show an improvement in students' performance after the classroom implementation, but they cannot be used to confirm that the improvement was caused by the card game alone.

Third, the analysis in this study mainly used descriptive statistics and item-level analysis. This provided information on the changes in students' scores and showed which prefix associations were more difficult for the students. However, the analysis did not include inferential statistical tests. Future studies with a larger number of participants could include appropriate statistical tests, such as a paired-samples analysis, to provide further analysis of the pre-test and post-test results.

Fourth, the student perception survey was adapted from selected dimensions of GAMEFULQUEST, and the response format was changed to Yes/No. The Yes/No format was used to make the questionnaire simpler for the participating Pre-Diploma Science students, but it provided less detail about the students' level of agreement. Future studies could use a Likert-scale response format and further examine the adapted questionnaire. Open-ended questions or short interviews could also be included to obtain more information about the students' experiences while playing the game.

For future studies, a larger number of students from different groups could be included. A control or comparison group could also be used to compare the card-game activity with conventional teaching. This would provide a clearer comparison of students' performance before and after the intervention. A delayed post-test could also be conducted to examine whether students could retain the association between the prefix, symbol and power of ten after some time. Future studies could also examine whether the three-card family structure helps students to connect the prefix name, symbol and value more effectively.

Conclusion

This study investigated the implementation of Advanced Happy Family: Prefix Edition as an alternative game-based method to support students' learning of SI prefixes. The results showed an improvement in the overall student performance, with the mean score increasing from 11.84/18 in the pre-test to 14.37/18 in the post-test. More importantly, the improvement was greater for the symbol-to-value association, which was the weaker component in the pre-test. The mean score for this component increased from 38.0% to 62.6%, while the prefix-to-symbol association increased from 93.6% to 97.1%.

The item-level results showed greater improvement in several symbol-to-value associations, particularly $p \rightarrow 10^{-12}$, $c \rightarrow 10^{-2}$, and $m \rightarrow 10^{-3}$. The three-card family learning method requires students to connect the prefix, symbol and value to complete a family. This approach may help students to remember the relationship between these three representations of SI prefixes.

The students also reported positive experiences with the card game. Social Experience, Competition and Playfulness recorded high positive responses, while Immersion and Challenge also received positive responses. Overall, Advanced Happy Family: Prefix Edition has potential as a classroom activity to support learning of the prefix–symbol–value relationship in an enjoyable and interactive way.

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