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IMPROVING STUDENTS' ABILITY TO ASSOCIATE PHYSICAL QUANTITIES WITH SI UNITS THROUGH TEMPUR SAINS: A GAMIFIED CARD GAME APPROACH

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Abstract:

TEMPUR SAINS was developed as a card game to help students associate physical quantities with their corresponding SI units. Sixteen Form 4 students from a Science STEM A class participated in the evaluation. A 16-item matching test was given before and after the game session. The mean score increased from 7.63 in the pre-test to 11.94 in the post-test. Improvement was observed in 15 of the 16 physical quantity-SI unit pairs. The largest increase was found for *ketumpatan*, where the correct responses increased from 18.75% to 81.25%. The results show that TEMPUR SAINS can be used as a supplementary activity to practise the association between physical quantities and SI units. Further evaluation with a larger number of students and matched pre-test and post-test responses is recommended.

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Keyword:

Educational Card Game; Game-Based Learning; Gamification;
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Introduction

Understanding physical quantities and their corresponding International System of Units (SI) is fundamental to science and physics education (Oğuzhan Dinçer & Osmanoglu, 2018). SI units provide a standardized way of expressing measurements and enable scientific information to be communicated consistently. For students, knowledge of physical quantities and SI units is also important when interpreting physics problems, identifying given variables, selecting appropriate equations, and presenting answers with the correct units (Redish, 2021).

Despite their importance, students may find it difficult to remember and correctly associate physical quantities with their SI units (Ürek, 2020). This difficulty can affect their ability to interpret information in physics questions and may result in errors when solving problems (Amos et al., 2020). Learning that relies mainly on memorisation may also provide limited opportunities for students to repeatedly practise and apply these associations in an active learning environment (Freeman et al., 2014).

Gamification has been increasingly used in education to make learning more interactive and engaging (Dichev & Dicheva, 2017). By incorporating game elements into learning activities, students can be encouraged to participate actively while repeatedly engaging with the learning content (Manzano León et al., 2021). A meta-analysis by Sailer and Homner (2020) found that gamification can have positive effects on cognitive, motivational, and behavioural learning outcomes. In physics education, Ab Patar et al. (2024) also reported a positive effect of gamification on students' learning of fundamental physics concepts. Besides incorporating game elements into learning activities, games can also be used directly as a learning activity. This approach allows students to learn and practise specific content through gameplay.

Educational card games are one of the game-based learning activities that can be used in the classroom (Sousa et al., 2023). They are simple to use and do not require digital devices. Students can also interact with each other during the activity (Ariya et al., 2025). Lhardy et al. (2022), for example, developed *Unit Kemps*, a card game for learning physical quantities, units, symbols, and measuring instruments. Their study showed that the card game could support students' learning while providing an enjoyable learning experience. This provides an example of how card games can be used to reinforce students' knowledge of physical quantities and SI units.

Other card-based resources have also been developed for learning SI-related concepts. Lazarevic et al. (2024) reported NTC4memory, a memory-based card game that uses symbols, SI units, and picture-based associations to support learning of physical quantities and units. Jagoda & Benham (2023) developed the NIST SI Units Card Deck, which provides a broader card-based resource with several game variations covering different elements of the SI system, including base units, derived units, and prefixes. These existing resources show that card games can be used to support learning about physical quantities and SI units, but they differ in their content, design, and language context.

TEMPUR SAINS was developed as a focused card game for practising the association between physical quantities and their corresponding SI units. The game was inspired by Halli Galli, mainly in terms of focus and rapid response. Instead of fruit pictures and a bell, a similar fast-response element is used to match physical quantities with their corresponding SI units. Action cards were also included and were inspired by game elements commonly found in UNO (Piyawattanaviroj et al., 2019). These cards add variety to the gameplay and make the activity more interactive.

TEMPUR SAINS was also developed in Bahasa Melayu to suit the Malaysian school context. Bahasa Melayu is the main medium of instruction in national schools in Malaysia, including in the teaching of Science and Mathematics. In comparison, *Unit Kemps* is available in English, French, and Spanish, while NTC4memory uses symbols, SI units, and picture-based associations. The NIST SI Units Card Deck also provides its instructional materials in English. Therefore, the use of Bahasa Melayu provides a language-specific feature of TEMPUR SAINS for use in the Malaysian school context.

TEMPUR SAINS also uses a colour-matching design. Each physical quantity card and its corresponding SI unit card have the same colour. This feature was included to help beginners (Meusel et al., 2024), particularly students who have limited prior science knowledge. The colour can be used as a visual guide when students are learning the correct physical quantity–SI unit pairs. The cards can also be used individually as flashcards for self-learning (Ingebrigtsen et al., 2025), allowing students to practise the matching activity without playing with other students.

The main contribution of this study is the design of TEMPUR SAINS as a non-digital card game focused on associating physical quantities with their corresponding SI units in Bahasa Melayu. Therefore, this study aimed to examine changes in students' ability to associate physical quantities with SI units after using TEMPUR SAINS. The study compared students' overall performance before and after the intervention and examined the changes for individual physical quantity–SI unit pairs.

Methodology

Development of TEMPUR SAINS

TEMPUR SAINS was developed using Canva. All cards were written in Bahasa Melayu, and the physical quantities included were selected from the Malaysian Science syllabus for Form 1-3. The cards were printed in the same size as commercial card games.

The game consists of 17 physical quantity cards, 17 SI unit cards, 5 action cards, and a set of three instruction cards. The instruction cards are arranged in sequence to provide the complete guide on how to play TEMPUR SAINS. Each player is provided with an identical set of SI unit cards. Figure 1 shows components of the TEMPUR SAINS card game. Before the game begins, the physical quantity cards and action cards are randomly shuffled together and placed face down in the centre to form the deck.

During gameplay, players take turns revealing cards from the deck. Each player then quickly identifies the corresponding SI unit card from their own set. The first player to match the correct SI unit card wins the round. The game is designed for 2–4 players, with an estimated playing time of 15–20 minutes for one round.



Figure 1: Components of the TEMPUR SAINS card game: (a) selected physical quantity cards, (b) corresponding SI unit cards, (c) action cards, and (d) instruction cards

Participants

The study involved 16 Form 4 students who volunteered to participate from a Science STEM A class in a regular secondary school. This was the only Science STEM A class in the school, and the students studied Physics, Chemistry, Biology, and Additional Mathematics. The other Form 4 classes studied Science as a subject without taking these four subjects. The participants had previously been exposed to the physical quantities included in TEMPUR SAINS when

they studied Science at the lower secondary level. The intervention was conducted under the supervision of a teacher.

Assessment Instrument

A matching test was developed to assess students' ability to associate physical quantities with their corresponding SI units. The test items were developed based on the physical quantities and SI units included in TEMPUR SAINS. Before the test was printed and administered, the items were carefully checked by the researcher to ensure that the physical quantity–SI unit associations were accurate and consistent with the SI system. The test was written in Bahasa Melayu, consistent with the language used on the cards. The test consisted of 16 scored items, with a maximum score of 16 marks. One example, matching the physical quantity *jarak* with the SI unit *meter*, was provided as a reference for students and was not included in the scoring. The same test was administered before and after the intervention. Students were instructed not to write their names or any identifying information on the test papers, allowing the responses to remain anonymous.

Intervention Procedure

The students first completed the pre-test. The researcher then introduced TEMPUR SAINS and explained the game rules before the students were divided into four groups of four. Each group played several rounds of the game under the supervision of a teacher. 1 round of the game was approximately 15–20 minutes. Following the gameplay session, the students completed the same matching test as the post-test.

Data Analysis

Descriptive statistics were used to examine the pre-test and post-test scores, focusing on the mean, median, standard deviation, minimum, maximum, and range.

An item-level analysis was also conducted to determine the number and percentage of students who correctly matched each physical quantity with its corresponding SI unit before and after playing TEMPUR SAINS. Changes in item performance were reported in percentage points.

Result and Discussion

Overall Performance

The descriptive results showed that the students obtained higher scores in the post-test. As shown in Table 1, the mean score increased from 7.63 in the pre-test to 11.94 in the post-test. The median score also increased from 7.50 to 13.50, while the mode increased from 10 to 14. Based on the maximum score of 16, the mean score increased from 47.7% to 74.6%. These results show that the students generally performed better after using TEMPUR SAINS.

The minimum score increased from 3 to 6, while the maximum score increased from 14 to 16. The range decreased from 11 to 10 marks. The increase in the minimum score shows that the students with the lowest pre-test scores also showed improvement. The increase in the maximum score shows that some students obtained the full mark in the post-test. However, the small difference in range shows that the spread of the scores did not change much.

The standard deviation was 3.3040 for the pre-test and 3.2958 for the post-test. The values were very close, indicating that the variation in students' scores was almost similar in both tests. Therefore, the increase in the mean score was not accompanied by a large change in the spread of the scores.

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

Statistic	Pre-test	Post-test
Mean	7.63	11.94
Median	7.50	13.50
Mode	10	14
Standard deviation	3.3040	3.2958
Minimum	3	6
Maximum	14	16
Range	11	10
Pearson's skewness	0.1135	-1.4223

Pearson's skewness decreased from 0.1135 in the pre-test to -1.4223 in the post-test. The pre-test score distribution was close to symmetrical, while the post-test showed a negative skewness. This indicates that more students obtained higher scores in the post-test. This result is also supported by the higher median, mode, and maximum score obtained in the post-test.

The improvement in students' performance is related to previous findings on game-based learning. A meta-analysis by Wang et al. (2022), which examined 33 studies involving 3,894 students, reported a moderate positive effect of digital game-based STEM education on students' learning achievement compared with other instructional approaches. Although TEMPUR SAINS is a non-digital card game, the finding provides support for the use of game-based approaches to reinforce learning in STEM education.

Card games may also provide opportunities for repeated engagement with specific learning content. Kordaki and Gousiou (2017), in a systematic review of educational digital card games, reported that card games had been used across different educational levels and subject areas, with many studies reporting positive outcomes related to learning, attitudes, and social interaction. This is relevant to TEMPUR SAINS because the game requires students to repeatedly identify and match physical quantities with their corresponding SI units during gameplay.

The observed improvement may also be related to the opportunity for students to retrieve previously learned information while playing (Yang et al., 2021). Retrieval practice has been shown to support learning more effectively than some forms of repeated studying, particularly when learners are required to actively recall information (Adesope et al., 2017). Karpicke and Blunt (2011) found that retrieval practice produced greater gains in meaningful learning than elaborative studying with concept mapping. In TEMPUR SAINS, students repeatedly recall the appropriate SI unit when a physical quantity card is revealed. However, the present study did not separately measure the role of retrieval practice, and therefore this explanation should be considered as a possible mechanism rather than a confirmed cause of the improvement.

Overall, the descriptive findings indicate a positive shift in students' performance after participating in TEMPUR SAINS. Nevertheless, the results should be interpreted as an observed improvement rather than definitive evidence of a causal effect, because the study involved only 16 students and the anonymous pre-test and post-test responses could not be individually matched.

Item-Level Performance

Table 2 presents the percentage of students who correctly matched each physical quantity with its corresponding SI unit before and after the intervention. The results showed that 15 of the 16 items recorded an increase in correct responses, while one item showed no change.

Table 2: Students' Correct Responses for Each Physical Quantity-SI Unit Pair in the Pre-test and Post-test

Physical quantity → SI unit	Pre-test (%)	Post-test (%)	Gain (pp)
<i>jisim</i> → kilogram	93.75	100.00	+6.25
<i>masa</i> → saat	87.50	100.00	+12.50
<i>suhu</i> → Kelvin	43.75	87.50	+43.75
<i>arus elektrik</i> → ampere	50.00	75.00	+25.00
<i>halaju</i> → meter per saat	50.00	56.25	+6.25
<i>pecutan</i> → meter per saat kuasa dua	56.25	56.25	0.00
<i>daya</i> → newton	81.25	87.50	+6.25
<i>tekanan</i> → pascal	18.75	56.25	+37.50
<i>tenaga</i> → joule	18.75	56.25	+37.50
<i>kuasa</i> → watt	25.00	50.00	+25.00
<i>haba tentu</i> → joule per Kelvin	25.00	56.25	+31.25
<i>kapasiti haba tentu</i> → joule per kilogram per Kelvin	12.50	56.25	+43.75
<i>voltan</i> → volt	68.75	87.50	+18.75
<i>rintangan</i> → ohm	31.25	87.50	+56.25
<i>frekuensi</i> → hertz	87.50	100.00	+12.50
<i>ketumpatan</i> → kilogram per meter padu	18.75	81.25	+62.50

Note: Gain (pp) = post-test percentage – pre-test percentage

The highest improvement was found for *ketumpatan*, where the correct responses increased from 18.75% in the pre-test to 81.25% in the post-test, with an increase of 62.50 percentage points. This was followed by *rintangan*, which increased from 31.25% to 87.50%, with a gain of 56.25 percentage points. The percentage of correct responses for *suhu* and *kapasiti haba tentu* increased by 43.75 percentage points each. Meanwhile, *tekanan* and *tenaga* each showed an increase of 37.50 percentage points.

Other items also showed improvement. Correct responses for *kuasa* increased from 25.00% to 50.00%, while *arus elektrik* increased from 50.00% to 75.00%. The percentage of correct responses for *haba tentu* increased from 25.00% to 56.25%, and *voltan* increased from 68.75% to 87.50%. Smaller increases of 6.25 percentage points were recorded for *jisim*, *halaju*, and *daya*. Meanwhile, *masa* and *frekuensi* increased by 12.50 percentage points.

The percentage of correct responses for *pecutan* remained unchanged at 56.25% in both the pre-test and post-test. This was the only item that did not show an increase. The high pre-test score for some items may also explain the smaller improvement. For example, *jisim* already recorded 93.75% correct responses in the pre-test, with only a small increase to 100.00% in the post-test.

The higher improvement was found for items such as *ketumpatan*, *rintangan*, *suhu*, and *kapasiti haba tentu*, which recorded lower correct responses in the pre-test. During the game, students repeatedly identified the SI unit when the physical quantity card was shown. This gave students more opportunities to practise matching the physical quantities with their SI units (Rowland, 2014). However, the learning process during the gameplay was not measured in this study. Therefore, the reason for the improvement cannot be confirmed.

The use of card games can also support students' learning through repeated interaction with the learning content. Kordaki and Gousiou (2017) reported that educational digital card games have been used in different disciplines and educational levels, with positive results reported in several studies. Science card games have also been used to support students in learning specific scientific content (TzuFen et al., 2014). For example, Liu and Chen (2013) reported that students' science knowledge improved after using the educational card game *Conveyance Go*. The result for *pecutan* remained unchanged at 56.25% in both the pre-test and post-test. This shows that the improvement was not the same for all physical quantity–SI unit pairs. Some pairs may need more explanation, examples, or practice in addition to the card game. Therefore, TEMPUR SAINS can be used as a supplementary learning aid to provide additional practice and should not replace the usual classroom teaching (Tursyngozhayev et al., 2024).

Overall, 15 of the 16 items showed higher correct responses in the post-test. The higher improvement was mainly found for items with lower pre-test scores. Together with the increase in the overall score, the results show that TEMPUR SAINS can be used as a supplementary gamified activity to help students practise associating physical quantities with their corresponding SI units.

Limitations and Future Studies

This study involved only 16 students who volunteered to participate in one Science STEM A class in a regular secondary school. Therefore, the findings may not represent students from other classes, schools, or different academic backgrounds.

The same test was used for the pre-test and post-test. The students did not write their names on the test papers, so the scores could not be matched individually. For this reason, the analysis was limited to descriptive statistics and comparison of the item-level results. The use of the same test may also have allowed students to become familiar with the test items.

The intervention was carried out over several rounds of gameplay, with each round taking approximately 15–20 minutes. The students completed the post-test after the gameplay sessions. Therefore, this study only shows the changes in students' performance after the gameplay activity. It does not show whether the students could remember the physical quantity–SI unit associations for a longer period.

For future studies, TEMPUR SAINS can be tested with a larger number of students from different classes or schools. Students' pre-test and post-test responses can also be matched to allow further statistical analysis and more detailed examination of individual changes in performance. A control group can be included to compare students who use TEMPUR SAINS with those who learn the topic using the usual learning activities. A delayed post-test can be conducted after several weeks to determine whether the students can still remember the physical quantity–SI unit associations.

Future studies can also examine the use of TEMPUR SAINS in different language and school contexts, including an English version of the card game. Students' responses towards the game, such as their interest, enjoyment, and perceived usefulness, can also be studied.

Conclusion

TEMPUR SAINS provides a simple and interactive way for students to practise matching physical quantities with their corresponding SI units. The results showed an increase in the students' overall performance after using the card game. Most of the physical quantity–SI unit pairs also showed higher percentages of correct responses in the post-test. The largest improvement was found for *ketumpatan*, followed by *rintangan*, while *pecutan* showed no change. These results show that TEMPUR SAINS can be used as a supplementary activity to help students practise and reinforce the association between physical quantities and SI units in science education. Further studies with larger samples and stronger research designs are recommended to examine its effectiveness and learning retention.

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