JPII 15 (2) (2026) 344-359

Jurnal Pendidikan IPA Indonesia

https://journal.unnes.ac.id/journals/jpii

ORGANIC COMPOUNDS LEARNING GAME TO PROMOTE TWELVE GRADERS' ACADEMIC ACHIEVEMENT AND ATTITUDES TOWARD CHEMISTRY IN THAI ISLAMIC PRIVATE SCHOOL

R. Safkolam*[1] & P. S. Sinchai[1]

[1]Faculty of Science Technology and Agriculture, Yala Rajabhat University, Thailand

DOI: 10.15294/jpii.v15i2.35738

Accepted: October 31st, 2025. Approved: June 29th, 2026. Published: June 29th, 2026

ABSTRACT

Organic chemistry is a crucial subject in chemistry. Its abstract nature can make it difficult for students to understand. Learning games are an educational innovation that can improve learning outcomes and motivate students in chemistry. This study aims to develop and test the efficiency of a learning game on organic compounds, compare students' academic achievement before and after learning, and examine students' attitudes toward chemistry. A one-group pretest-posttest design was used. The participants were 19 Grade 12 students in an Islamic private school in Thailand, selected through purposive sampling. The research instruments included 1) a learning game on organic compounds, 2) an achievement test on organic compounds, 3) an attitude toward chemistry questionnaire, and 4) a semi-structured interview on attitudes toward chemistry. Data were analyzed using percentages relative to the efficiency criterion (E1/E2) of 75/75 percent, mean, and standard deviation, paired t-test, and qualitative data were analyzed using content analysis. The results showed that the learning game's efficiency was 78.95/80.79. The average post-learning achievement score was statistically significantly higher than the pre-learning score at the .05 level. The students' attitudes toward chemistry were highly positive ($\bar{X}$ = 3.65, S.D. = 0.33). The research supports game-based learning, highlighting that play lowers anxiety and increases engagement. It demonstrates that educational games can promote equity by assisting students, particularly low achievers, and by encouraging active learning in science classes. The study finds that game-based learning enhances upper secondary students' performance in chemistry and attitudes toward the subject. Educators are encouraged to integrate learning games into science lessons to create a more engaging, equitable, and student-focused environment.

Keywords: learning games; academic achievement; attitude toward chemistry; Islamic private school

INTRODUCTION

The main goal of science learning management in Thailand and internationally is to develop all students into science-literate people. This refers to an individual who can engage in science by searching for data, evaluating and analyzing scientific knowledge, and explaining or predicting natural phenomena that occur in everyday life (Almeida et al., 2023; Rudolph, 2024). These individuals play a crucial role in the country's development and advancement of science. These goals align with the United Nations' Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education), which aims to ensure inclusive and equitable access to quality education for all learners (United Nations, 2015; UNESCO, 2021). Therefore, teachers must create a meaningful classroom atmosphere for science learning, which has many fields, including physics, chemistry, and biology. Every field connects to everyday life. More specifically, chemistry is the study of matter, including its composition, structure, and properties, as well as chemical reactions

***Correspondence Address**
E-mail: roswanna.s@yru.ac.th

(Chen & Chu, 2020), and learning chemistry aims to provide students with an understanding of the nature and changes of matter (Stammes et al., 2023). In addition, chemistry is important across many fields of education, including health sciences, geology, physical sciences, environmental sciences, and business. Moreover, knowledge of chemistry helps make human decisions about health. Chemistry is also a science that promotes human awareness of environmental issues, including pollution and the maintenance of environmental balance (Wiyarsi et al., 2020; Phajan et al., 2025; Sah et al., 2025).

Although chemistry plays a vital role in our daily lives, both directly and indirectly, and is one of the main goals of learning science, most students struggle to learn the subject and have difficulty understanding it (Dood & Watts, 2022; Pratomo et al., 2025). Students demonstrated academic achievement and negative attitudes towards chemistry, leading educators to attribute the difficulty of chemistry to abstraction (Musengimana et al., 2021; Nieto-Escamez &Roldán-Tapia, 2021; Wang et al., 2021). The explanation is not sufficiently detailed. It makes students unable to imagine. Students struggle to comprehend the fundamental principles of chemistry. Most explanations in Thai chemistry textbooks use scientific terminology, chemical structures, and bonds, particularly in organic chemistry, which primarily studies organic compounds containing carbon (Kavak et al., 2021). Students must thoroughly understand this subject, as it is crucial to other fields of chemistry (Gupte et al., 2021; Hermanns et al., 2023). Recent national assessments reveal persistent underperformance in science education among Thai upper secondary students. According to the Ordinary National Educational Test (O-NET) results from academic years 2021 to 2023, students scored average marks of 28.65, 28.08, and 29.09, respectively, in the Science and Technology learning area (NIETS, 2024).

Furthermore, the Applied Knowledge Level (A-Level) examination in 2023 reported an average chemistry score of 18.40 out of 100 (Council of University Presidents of Thailand, 2023). Particularly in Thailand's southern border provinces, where most students attend Islamic private schools, average science scores remain below the national standard (Churngchow & Sinprajukpol, 2016; Anantanukulwong et al., 2023). These results indicate that students still lack a solid understanding of chemistry content, especially in organic compounds, a key component assessed in both O-NET and A-Level examinations. Moreover, a deeper analysis of the learning environment reveals that instruction in many of these schools remains predominantly lecture-based, offering limited opportunities for student-centered or inquiry-driven learning. As a result, students often exhibit low levels of engagement and intrinsic motivation toward science. Compounding this issue is the widespread lack of access to high-quality instructional materials and essential laboratory equipment, which further impedes effective science teaching and learning (Vasinayanuwatana et al., 2019).

Furthermore, this school operates within a unique cultural setting that greatly influences chemistry education. Most students speak local Malay dialects, whereas classroom instruction predominantly uses Standard Thai (Ayae & Savski, 2024; Wanaeloh et al., 2024), creating an additional challenge for understanding chemistry concepts. Furthermore, the curriculum at this school is dual, combining Islamic religious studies with the basic education program, resulting in less instructional time than in public schools (Lateh et al., 2025; Yusuf & Thongin, 2025), which may limit students' active participation in interactive learning activities.

Based on the above problems, teachers should find strategies or learning materials that help students see and understand these concepts. Most importantly, teachers should make students knowledgeable and have fun, leading to a positive attitude toward chemistry. The challenge in studying chemistry lies in using symbols. Students must comprehend the lesson's symbols and their meanings. Students will be able to comprehend the concept in question (Taber, 2020). The game incorporates lesson content, enabling students to engage in hands-on learning and self-learning exercises. Students will gain skills and knowledge from the lesson's content (Bulut et al., 2022). This leads students to gain knowledge and enjoyment simultaneously, fostering a cooperative learning environment that prepares them to learn independently (Feng et al., 2024). It encourages students to participate in every step of the learning process. Students will experience increased excitement, motivation for learning, and a more positive attitude towards learning through games (Chen et al., 2020; Yu et al., 2021). It can also enhance students' comprehension of the content, spark their interest in the lesson, and foster the development of more scientific ideas (Franco-Mariscal et al., 2016; Nuha & Purwanti, 2023). In addition, a review of international research indicates that game-based learning is an effective approach for promoting students' achievement and understanding of chemistry concepts. Wardani et al. (2017) developed an Android-based chemistry board game to promote learning outcomes and critical thinking skills, and Korkmaz et al. (2023) found that the development of educational games affected students' achievement and attitudes toward science. Although previous research has shown the effectiveness of game-based learning in chemistry, significant gaps remain. A key finding is that most research on learning games for organic compounds is conducted at the undergraduate level (Reina et al., 2022; Teo et al., 2025), and there is a lack of studies in the context of Islamic private schools. Furthermore, much of the research focuses solely on the cognitive domain. Neglecting the affective dimension, which is a crucial factor for long-term success in chemistry studies (Hu et al., 2022; Crucho et al., 2025), and research focusing on twelfth-grade students in their final year, a transitional period before entering higher education, remains limited.

This research builds upon and supports previous research on game-based learning in chemistry, with three novel aspects: (1) developing a learning game on organic compounds, (2) testing it with Grade 12 students in Thai Islamic private schools, where no previous research has been conducted, and (3) measuring both achievement and attitude toward chemistry. The following research questions are addressed: (1) Is the developed learning game on organic compounds efficient according to the established criteria? (2) Does students' academic achievement significantly improve after participating in the learning game on organic compounds? (3)What are the students' attitudes towards chemistry after using the learning game? This learning game will guide science teachers in creating innovative lessons in chemistry and other subjects for classroom management and inspire them to continue developing related content in the future.

METHODS

Nineteen twelfth-grade students from an Islamic private school in Yala province, southern Thailand, participated. They were obtained through purposive sampling, selecting schools based on the following criteria: an Islamic private school with low chemistry achievement, a school that could represent Islamic private schools in Yala province, and a school that lacked science learning materials. Although selecting a target group using this method may limit the generalizability of research findings to other populations, this research aims to conduct in-depth studies within the specific context of Islamic private schools, which have cultural, linguistic, and curricular structures distinct from those of public schools.

This research has a quasi-experimental research methodology. A one-group pretest-posttest design (Cohen et al., 2000) was used. Although this research employed a one-group pretest-posttest design due to the contextual limitations of the Islamic private school, the researchers systematically implemented Measures to control internal validity and reduce the influence of confounding variables. These measures were as follows: First, the researchers directly managed the learning process using the learning game on organic compounds throughout the 13-hour experiment, which comprised a 1-hour pre-test, 12 sessions (50 minutes each), a 1-hour post-test, and a 1-hour examination of attitude towards chemistry after learning. This was done to maintain consistency in the teaching process and prevent inter-teacher variability. Second, the experiment and data collection were conducted during regular class hours to reflect the authentic learning context and minimize the influence of external factors that might affect the validity of the research results. Third, the researchers conducted a pre-test to establish a baseline for comparing students' learning progress after completing the learning game on organic compounds.

The tools used in the research include a learning game on organic compounds, an academic achievement test, an attitude towards chemistry questionnaire, and a semi-structured interview form about attitude towards chemistry.

The learning game about organic compounds to be used during the learning activity stage consists of four dominoes. The first set of hydrocarbon compounds consists of 1) alkane, 2) alkene, 3) alkyne, and 5) aromatic hydrocarbons. The second set is organic compounds containing oxygen or nitrogen as a single bond, consisting of 1) alcohol, 2) phenol, 3) ether, and 4) amine. The third set is a series of organic compounds containing carbonyl groups, consisting of 1) aldehyde, 2) ketones, 3) carboxylic acid,4) esters, and 5) amides, and the fourth set of organic compounds, which consists of 1) alkane, 2) alkene, 3) alkyne, 4) aromatic hydrocarbons, 5) alcohol, 6) phenol, 7) ether, 8) amines, 9) aldehydes,10) ketones, 11) carboxylic acid, 12) esters, and 13) amides. Each set of learning games on organic compounds contains 20 exercises, each a multiple-choice test with four options.

According to the ADDIE MODEL, the researcher created a learning game on organic compounds with five stages: analyze, design, develop, implement, and evaluate (McGriff, 2000). Each step is detailed as follows:

Analyze

Guidelines for managing science learning in the Basic Education Core Curriculum B.E. 2551 (A.D., 2008) (Ministry of Education Thailand, 2008). This includes the academic achievement of twelfth-grade students in private Islamic schools, as well as approaches to the management of science education under the National Education Act of 1999 (A.D., 2002). The study focuses on the goals of science learning, learning games, and domino games, drawing on relevant documents and research. The researcher compiled scientific concepts from twelfth-grade science textbooks to create a domino game on organic compounds and related concepts and theories. Finally, the researcher gathered information from relevant documents and research on learning games and the creation of domino games to design and develop the learning game on organic compounds.

Design

This phase involves designing a learning game about organic compounds. The researcher's creation of domino games, along with related documents and research, considers the suitability of the target group and the content to be measured for use as a learning game.

Develop

After designing a learning game, Organic Compounds, the researchers were assigned to 3 experts, including two experts in science education and one content expert, who were evaluated by the index of congruence (IOC), which must be 0.5 or higher (Bergman, 1996), to evaluate the appropriateness of the elements in learning games. Organic compounds have the main characteristics. The learning process at each stage was created. The role of students and teachers in learning games focuses on organic compounds, content coverage, and the language used, with experts evaluating and selecting texts that have an integrity index (IOC) value of 0.50 or higher (Bergman, 1996). The consistency index is between 0.67 and 1.00, which is greater than 0.5 (Bergman, 1996). The suitability value of the learning game for organic compounds, as rated by experts, is 4.00-4.67, with an average of 4.34, which is classified as a high level. Therefore, the developed game is considered appropriate and applicable for use in science instruction. Based on the experts' feedback, the researcher made revisions to improve the learning game and enhance its effectiveness for classroom implementation. After revising the learning game on organic compounds according to expert recommendations, the researcher tested the efficiency of the learning game by a large group (1: 100) try-out according to the criteria of Brahmawong (2013), the 75/75 percent criterion, by conducting a pilot study with 31 students who were not part of the sample group but had similar learning abilities and school contexts. The try-out results showed that the process efficiency (E_1) was 83.47 and the outcome efficiency (E_2) was 84.68, demonstrating that the learning game on organic compounds had an efficiency of 83.47/84.68.

The researchers personally facilitated the learning process to assess the feasibility of the learning game on organic compounds. Each game box lacked a specification of the type of organic compound, making it possible for students to distinguish which box to start and end. Therefore, the researcher modified the front design of the game box by labeling each type of organic compound to correspond with the color of each domino category, as follows: hydrocarbon compounds (green), organic compounds with oxygen or nitrogen as elements with a single bond (red), organic compounds with carbonyl group as element (yellow) and all types of organic compounds (green, red, and yellow).

Implementation

After developing a learning game on organic compounds, the researcher implemented it with the target group throughout the 13-hour experiment.

Evaluation

The researcher's evaluation focused on two dimensions. Students' academic achievement was assessed with an achievement test administered before and after the intervention, and scores were compared using a paired-samples t-test. Students' attitudes toward chemistry were examined after the intervention using an attitude questionnaire and a semi-structured interview.

The academic achievement test on organic compounds is a multiple-choice test with 4 choices and 40 questions. The assessment results showed that the index of congruence ranged from 0.67 to 1.00, exceeding 0.5 (Bergman, 1996), and validated the academic achievement test based on expert recommendations and feedback. Then, we tested students who were not the target group of 31 people to determine the classification power (0.38-1.00), the difficulty (0.44-0.88), and the Kuder-Richardson (KR-20) formula, which was found to be 0.76.

Attitude towards chemistry questionnaire created. It is characterized by a 5-level approximation scale with 24 questions. The questions each aspect of the attitude towards science of the Institute for the Promotion of Science and Technology (IPST) (IPST, 2002), including 1) Interest in chemistry, 2) Appreciation of chemistry, 3) Beliefs and values related to chemistry, and 4) Morality and ethics related to chemistry. The results of the evaluation showed that the index of consistency between the text and the aspect of attitude towards chemistry to be measured ranged from 0.67 to 1.00, which was greater than 0.5 (Bergman, 1996), and validated the questionnaire on attitude towards chemistry based on expert recommendations and feedback. Then, we tested the questionnaire on 31 non-participating students to determine its reliability in measuring attitudes towards chemistry. The Cronbach's alpha was 0.80 (Cronbach, 1990).

The researchers created a semi-structured interview on attitudes towards chemistry. Students can express their opinions and give reasons for their attitudes towards chemistry based on their responses. The interviews will yield qualitative data. To determine the quality of the interviews, the researcher examined the consistency of the interviews by having 3 experts in science education, and it was found that the index of consistency between the questions and the aspects of attitudes towards chemistry to be measured ranged from 0.67 to 1.00, which was more than 0.5 (Bergman,1996). A semi-structured interview on attitudes towards chemistry was conducted with non-target-group grade 12 students. The results showed that students understood the questions and could answer them appropriately.

Before conducting the research, the researchers clarified and explained the learning game, including its characteristics, gameplay, and rules, to ensure mutual understanding between students and teachers. They also provided details about the academic achievement test, the attitude toward chemistry questionnaire, and semi-structured interviews on attitude toward chemistry. For the collection of data on academic achievement and attitude towards chemistry:

The researchers evaluated students› academic achievement before learning about organic compounds using the academic achievement test. The time to answer the achievement test is 60 minutes. The researchers collected the achievement test and further analyzed the statistical results.

Students were divided into groups of 4–5 to play learning games about organic compounds. During the game, the researcher served as a facilitator, guiding the students. After each set of games, the students completed exercises developed by the researcher to review and assess their understanding. After that, the researcher discussed the findings with the students and concluded. The researcher obtained the sample group's permission to record the learning activities.

After finishing all the learning games about organic compounds. The researchers evaluated students› academic achievement after learning about organic compounds using the academic achievement test and measured students› attitude towards chemistry after learning with games using the attitude towards chemistry questionnaire. The researchers collected on-site data by measuring attitudes towards chemistry after class, giving students 60 minutes to express their opinions. The researchers collected the post-study measurements, analyzed the data, and interpreted the level of attitude towards chemistry.

The researcher conducted an in-depth semi-structured interview about students' attitudes towards chemistry after class. The interview questions were asked of 12 students. The researcher personally contacted the interviewee via mobile phone. All students agreed to be interviewed. The researcher scheduled one interview. Students can withdraw during the interview. In addition, the researcher clarified that the purpose of the interview was to elicit students' opinions on their attitudes towards chemistry. The students› answers do not have a "right" or "wrong" answer. In the students› opinions on each aspect of their attitude towards chemistry, the students› answers had no effect. The researcher gave students feedback to listen to the questions until they understood them clearly, and then to express their opinions truthfully. If the student does not understand the question, they can ask for clarification or request to hear it again. The researcher conducted semi-structured interviews with students about their attitudes towards chemistry, 1- 20 minutes each.

For this research, quantitative and qualitative data were analyzed. The efficiency of the learning game on organic compounds was determined by collecting scores from the organic compounds exercise, calculating the process efficiency (E1), and collecting post-class test scores. The academic achievement test on organic compounds was used to calculate the efficiency of the product (E_2). The two values (E_1 and E_2) were then used to calculate the learning game's efficiency using Brahmawong's (2013) efficiency formula.

Academic achievement is measured by administering a test to the target group before and after school, using learning games. Organic Compounds were analyzed, with 1 point for the correct answer and 0 points for the incorrect answer. The scores obtained from the achievement test were used. Organic compounds were analyzed before and after learning with organic compound learning games to calculate the average score, and the results were used to calculate the statistics for the test of the sample values, which are not independent of each other. The t-test for dependent samples (Ferguson, 1981) was used to compare the target group's average academic achievement scores before and after learning with learning games.

Attitudes toward chemistry were analyzed in two parts: quantitative and qualitative. Quantitative analysis: using learning games, a questionnaire was collected to measure the sample's attitude towards chemistry after the class. The researchers then analyzed the responses from the grading and interpretation of attitudes towards chemistry using the criteria of Rubba & Anderson (1978), as shown in Table 1.

Table 1. Comments on Scores of Positive and Negative Statements

Opinion	Positive messages (points)	Negative messages (scores)
Totally agree	5	1
Agree	4	2
Uncertain	3	3
Disagree	2	4
Strongly disagree	1	5

The researcher interpreted the mean scores to classify levels of attitude towards chemistry according to Srisaard's (2017) criteria, as shown in Table 2.

Table 2. Mean Scores and the Level of Attitude Towards Chemistry

Mean score	The level of attitude towards chemistry
4.50 -5.00	Very High
3.50-4.49	High
2.50-3.49	Moderate
1.50-2.49	Low
0.00-1.49	Very Low

The researcher collected qualitative data from students after they learned using learning games. The data were analyzed using content analysis (Schreier, 2012), in which the interview results were broken down, and the interviewees' sentences were arranged into the various aspects of their attitude towards chemistry.

Then, the analysis results were used to verify the accuracy and reliability of the research findings by sending the researcher's data analysis and interpretation to 3 experts in science education. The interviews were intended to support the quantitative data, in which each student's results were not specified by surname but only by a number, such as S02, S06, etc.

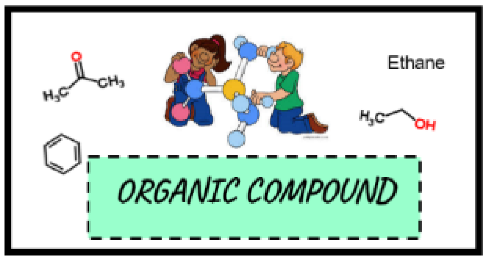

Figure 1. An Example of the Front Piece of Every Set of Learning Games

RESULTS AND DISCUSSION

Characteristics and efficiency of a learning game on organic compounds

The 4 sets of learning games on organic compounds consist of parts with 2 sides each, as shown in Figure 1.

For the learning game, the 4 sets of organic compounds consist of parts, each of which has 2 sides, as shown in Figure 2, and the back parts in each set of the learning game are divided into 2 compartments, which are as follows:

Set 1

Hydrocarbon compounds will have 2 green slots and black dots as points, divided into 2 types: Type 1 (types of hydrocarbon compounds) and Box 2. IUPAC NAME and Type 2, types of hydrocarbon compounds, and chemical structure of hydrocarbon compounds (Figure 2).

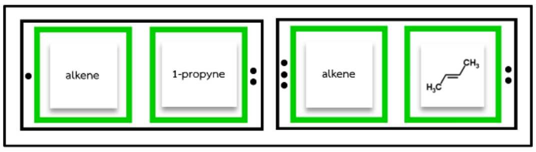

Figure 2. Example of the Back Piece of the Learning Game Set 1

Set 2

Organic compounds with oxygen or nitrogen as the element with a single bond have 2 red channels and black dots as several points, which are divided into 2 types: 1) Slot 1 is a type of organic compound with oxygen or nitrogen as an element with a single bond and channel 2 IUPAC NAME of an organic compound with oxygen or nitrogen as an element with each type of single bond. 2) Slot 1 is a type of organic compound containing oxygen or nitrogen as elements with single bonds, and channel 2: chemical structure of organic compounds containing oxygen or nitrogen as elements with each type of single bond, both parts of which are shown in Figure 3.

Figure 3. Example of the Back Piece of the Learning Game Set 2

Set 3

Organic compounds with carbonyl groups as elements have 2 yellow slots and black dots as the number of points, which are divided into 2 types: 1) Channel 1 types of organic compounds with carbonyl groups as elements and Channel 2 IUPAC NAME of organic compounds with carbonyl groups as elements. 2) Channel 1 types of organic compounds with carbonyl groups as elements and Channel 2 chemical structure of organic compounds with carbonyl groups as elements, both parts are shown in Figure 4, respectively.

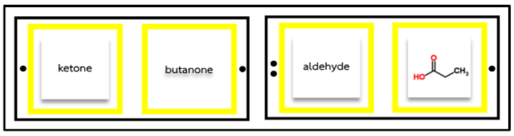

Figure 4. Example of the Back Piece of the Learning Game Set 3

Set 4

The fourth set of organic compounds consists of all types of organic compounds (hydrocarbons, organic compounds with oxygen or nitrogen as a single bond, and organic compounds with a carbonyl group). A set of learning games (green, red, and yellow), with colors displayed as several points.

The forms of the parts are divided into 2 types as follows: Type 1: Channel 1 (abbreviated structure) and Channel 2: IUPAC NAME of each type of organic compound, and Type 2: Channel 1: line and angle structure, and box 2 - chemical structure of each type of organic compound.

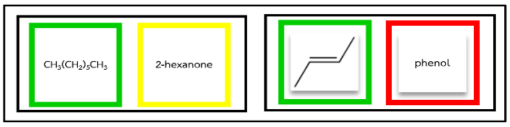

Figure 5. Example of the Back Piece of the 4th Set of Learning Games

The 4 pieces of the learning game "Organic Compounds" will be packed in a box with the rules described inside, as shown in Figure 6.

Figure 6. Example of a Box Containing Parts of a Learning Game on Organic Compounds

For the efficiency of the learning game on organic compounds, as shown in Table 3, the efficiency of the process (E_1) is 78.95, and the efficiency of the product (E_2) is 80.79. This shows that the learning game on organic compounds has an efficiency of 78.95/80.79, which exceeds the 75/75 percent criterion set by Brahmawong's efficiency formula (2013). The higher E_2 (80.79) than E_1 (78.95) provides empirical evidence that students effectively translate knowledge gained from the learning process into learning outcomes, indicating congruence between the learning process and the learning outcomes.

Table 3. Efficiency of Learning Games on Organic Compounds

Process efficiency (E_1)	Product efficiency (E_2)	Efficiency of the learning game (E_1/E_2)
78.95	80.79	78.95/80.79

From Table 3, this efficiency may result from a systematic game development process. The researchers tested the innovation's efficiency before implementing it and used the problems found to improve the learning game. When learning material has been tested for effectiveness, it is considered a teaching tool. It can create a picture of learning for students, enabling them to learn and change according to the teacher›s intended behavior (Prasertsin, 2020). This process aligns with the principles of instructional design, which emphasize the step-by-step analysis, design, development, implementation, and evaluation of instructional materials, as well as the important factors that affect the quality of instructional media (Branch, 2009). Saithongdee & Sirirat (2024) support this finding, showing that systematically designed and evaluated

chemistry board games can meaningfully boost academic achievement. Likewise, Li et al. (2022) demonstrated that cognitively focused chemistry board games improve learning outcomes and offer learners a high-quality play experience. Furthermore, the developed learning games address individual differences, with high-achieving students serving as scaffolds for lower-achieving students. This aligns with Vygotsky's (1978) concept of the Zone of Proximal Development (ZPD), which holds that learning is most effective when learners receive support from more knowledgeable others. The four sets of games, arranged from easy to difficult, align with Bloom's Taxonomy (Bloom et al., 1956), which prioritizes a progression from rote memorization to analysis and application. This allows students to continuously practice and develop their learning in line with their potential (Akour et al., 2020; Boghian & Cojocariu, 2023). There is an interesting arrangement of elements that is a reinforcement and encouragement for students (Demirkiran & Tansu Hocanin, 2021). In addition, the game includes numerous examples of each organic compound type, allowing students to practice continuously as they build their understanding throughout the lesson. Once students become familiar with the game, they will be enthusiastic about playing it until the end. Adipat et al. (2021) found that organizing classroom learning activities using games makes students feel enthusiastic and motivated to learn. Overall, this study confirms that quality game design, responsiveness to individual differences, and systematic content sequencing are important factors in the efficiency of learning games on organic compounds, consistent with the empirical evidence reported by Othman et al. (2025) that appropriately designed board games can effectively promote science learning and create positive learning experiences.

Students' academic achievement before and after school with learning games

Table 4 and Figure 7 show the average academic achievement scores before school with learning games.

Table 4. Academic Achievement Scores of Students Before and After Learning

Full score	Before learning		After learning		t	df	p	d	95% CI
		S.D.		S.D.					
40	12.11	2.66	32.32	3.92	23.68*	18	< .001	5.43	[18.42, 22.00]

*p < .05

This shows that students were taught with a learning game on organic compounds. The average academic achievement score after school was statistically significantly higher than before school at the .05 level.

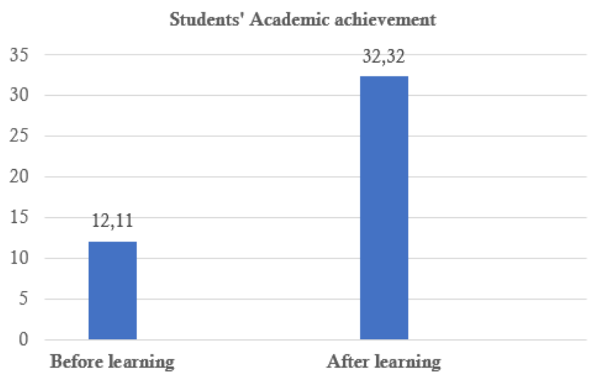

Figure 7. Mean Science Academic Achievement Scores of Students Before and After Learning

The pre- and post-school achievement tests, conducted through learning games on organic compounds, showed that students' average achievement scores after school were statistically significantly higher than before school at the .05 level. The rise in scores indicates that students' learning of organic compound content increased after using the developed domino game, reinforcing the idea that well-designed game-based learning can boost engagement and improve conceptual understanding more than traditional lecture-based teaching. This is consistent with Lutfi et al. (2023), who found that students who learned through games had higher academic achievement in chemistry and greater motivation to learn chemistry. Byusa et al. (2022) found that educational games consistently improve motivation and understanding of chemistry, supporting their findings. However, when compared with Miguel-Gómez et al. (2023), who developed a domino game for learning intermolecular forces, both studies showed similar results, indicating that domino games are an effective tool for promoting the learning of chemistry content that emphasizes memorization and matching relationships between compound structures and names. Partly because of the learning games, students exchange what they have learned, discuss together, share experiences, practice various skills to achieve learning objectives, and have fun. Games are suitable for children because they are activities children enjoy and provide fun and learning opportunities (Zeng et al., 2020; Arlinwibowo et al., 2023; Martinez Sainz et al., 2026). In line with Piaget›s theory, games serve as tools for children's intellectual development and social skills because, when playing, students interact with friends. Everyone will practice interacting with others and respecting rules. Learning to lose and win honestly, using games in teaching, or using games as a medium for managing learning are ways to reduce student stress. It provides students with fun and enjoyment. Students can study in a relaxed, stress-free environment (Badillo et al., 2026). Students tend to learn more from happy experiences than from unhappy ones. Therefore, games can create a positive learning experience for students and should be effective for learning (Flores-Aguilar et al., 2023). In addition, it may be because the game is designed to focus on students matching the structure and reading the names of each type of organic compound. In every content section, there are exercises for students to practice, which serve as a review to help them learn the content. The game will help students remember the content more effectively (Chu et al., 2023; Kochkarova & Turgunov, 2023).

The attitude toward chemistry among students who use learning games on organic compounds

The study found that after learning with a learning game on organic compounds. Students have a high overall attitude towards chemistry, as shown in Tables 5 and 6.

Table 5. Students' Mean Scores, Standard Deviations, and Attitudes Towards Chemistry

Item	$\bar{X}$	S.D.	Attitude level
1. I like to do chemical experiment activities.	4.47	0.51	High
2. I do not like participating in science projects related to chemistry.	3.68	0.75	High
3. I like to solve problems in chemistry.	3.00	1.37	Moderate
4. I do not like to study for more knowledge in chemistry.	3.53	0.96	High
5. I like to do exercises that relate to chemical structures and chemical reactions.	4.21	0.71	High
6. I do not like to watch videos about chemistry.	3.37	0.96	Moderate
7. I think that knowledge of chemistry can be applied in everyday life.	3.95	0.52	High
8. I think that studying chemistry makes us less conscious of preserving nature and the environment.t	3.32	1.46	Moderate
9. I think that knowledge of chemistry improves our quality of life.	3.16	1.02	Moderate
10. I do not think studying chemistry can be used as a basis for higher education.	4.42	0.51	High
11. I think that studying chemistry gives us systematic thinking.	3.95	0.52	High
12. I think studying chemistry makes us insecure in our lives.	3.68	0.95	High

Item		S.D.	Attitude level
13. I believe that knowledge of chemistry can be applied to solve everyday problems.	4.11	0.32	High
14. I believe that studying chemistry cannot be put to good use.	4.37	0.50	High
15. I believe that knowledge of chemistry gives us a better quality of life.	2.74	1.15	Moderate
16. I think that chemical advances have made us insecure in life.	2.63	1.38	Moderate
17. If I were to pursue higher education, chemistry would be my chosen field of study.	2.47	1.26	Low
18. I think that studying chemistry is not an essential basis for learning science.	3.79	0.86	High
19. I would like to organize a board about the benefits of chemistry in everyday life to spread my knowledge of chemistry to my classmates.	3.42	1.02	Moderate
20. I will not apply my knowledge of chemistry to the choice of everyday appliances.	3.63	1.07	High
21. How do I apply my knowledge of chemistry to make food decisions?	3.26	1.28	Moderate
22. When I watch a video of a chemical experiment, I do not want to explain that to my classmates.	3.95	0.97	High
23. If a friend does not experiment correctly. I will explain safety in chemistry labs to my friends.	4.42	0.51	High
24. I will not separate chemical waste, such as body spray, mosquito repellent spray, etc. When disposed of in the trash.	4.16	1.12	High
Average	3.65	0.33	High

Table 5 shows that the overall level of attitude towards chemistry was high (= 3.65, S.D.= 0.33). When considering the items, most students showed a strong attitude towards items 8, 10, 15, 16, 19, and 21. Students had a moderate attitude. In addition, students had a low attitude towards chemistry, as indicated by item 17.

In addition to the opinions from the chemistry attitude questionnaire, the researcher conducted in-depth interviews about attitudes toward chemistry after learning with the learning game on organic compounds, covering each aspect, using simple random sampling: three people per aspect, totaling 12 people. The example interview results are as follows:

Interest in Chemistry

The interviews found that students were more interested in chemistry when games were incorporated into their learning activities. The reason is that chemistry is a complex subject. When playing games and doing exercises, I better understand chemical structures, which helps me review the content and makes me want to study more chemistry.

"Doing exercises is a review of what you have learned. The more games come in, the more I understand. I want to play while doing exercises, which helps me feel more accurate in the content. Remember the name and structure of organic compounds." (S01)

"Sometimes, if you study in a classroom and do not understand all the material, you have to find out more information. From watching the YouTube teaching and playing the games, I remembered the structure, which made the game fun and understandable. When I could not find the answer, I searched the game›s manual and searched for more chemistry knowledge." (S01)

"I did not like doing exercises at all because it was difficult to do exercises. When the teacher adds a game, chemistry becomes easier. When I play the game, I can do the exercises, which makes it easier for me to remember the chemical structure and do the chemistry exercises." (S02)

"Before the game. I do not often find more chemistry knowledge; I only learn more during exams. However, when games supplement my chemistry class, I like to learn more so I can play games and do exercises after class. I want to know more about the chemical structure and chemical reactions." (S02)

Appreciation of Chemistry

The interviews found that students appreciate chemistry for its ability to teach systematic thinking and for its use in high-level education. The reason is that chemistry training involves planning systematically and step-by-step differentiation. Chemistry is a science and a basic subject that everyone must study at the university level. Organic compounds are especially the basis of chemistry that must be used for higher education. Sample student responses are as follows:

"Chemistry classes train us to plan systematically and procedurally, because chemistry requires learning about the structure and chemical reactions, the names of compounds, and the names of compounds. I found a structure; we had to remember to be precise, for example, I found an alcohol structure. -OH At the end of the chain, I have to think about it and find out that there is a piece of alcohol in our hands. It makes me have to plan and think." (S04)

"Chemistry is a sub-subject of science, and in order for us to study medicine and pharmacy, we must know about chemistry. Moreover, if we are doctors or pharmacists, we must know the chemical structure and composition of the drugs we prescribe or dispense. Moreover, organic compounds are a basic knowledge of chemistry. If we do not understand it, we will not be able to build on other chemical matters." (S04)

"Studying chemistry makes us think more systematically. When we did not know about chemistry, we felt chaotic. The game that I played helped a lot. In the game, there is a chemical structure and the name of an organic compound. I have to think about when I place the pieces: I have to place them correctly. How to continue? The structure itself is related to the type of organic compound." (S06)

"Chemistry is a basic subject that we must study at the university level, regardless of which faculty or field we study. When I write a chemical reaction, if you do not understand the chemical structure, you cannot write chemical reactions." (S06)

Beliefs and values related to chemistry

From the interview, it was found that Students believe that chemistry can be useful and that studying chemistry in higher education is valuable. The reason is that chemistry can be used to choose products safely. The name of the organic compound gives us an idea of the drug's ingredients. As a result of playing the game, the chemical structure is known. There is interest in studying chemistry at higher education institutions.

"Chemistry helps us to choose food; for example, we choose non-alcoholic foods. If we do not study chemistry, we will not know the chemical name of alcohol when the game book made me know. IUPAC NAME of alcohol, which is the name of the product's ingredients, you can know whether there is alcohol mixed or not mixed." (S02)

"If there were no teacher›s game yet. I will say no because chemistry is a very difficult subject, but when I have a teacher's game to supplement it, I find it easier. Therefore, it makes me want to continue studying chemistry. When I have a game, I understand more." (S02)

"Chemistry can be used for many purposes, such as safe shopping. If we know the chemical structure, for example, some people are allergic to alcohol when buying roll-ons. This tells us whether the product is alcoholic. As a result of the game, we know the name and the chemical structure; for example, we sometimes come across a chemical name that ends in -OH. You will know that this substance contains alcohol." (S07)

"Previously, I felt that chemistry was very difficult for me, but when a game came into my chemistry class, I tried it. Playing continued to make me understand more. I feel like chemistry, if I have the opportunity to continue studying, I will study chemistry when there are games that make me feel fun. I understand a lot; I have the motivation to continue studying chemistry." (S07)

Morality and ethics related to chemistry

The interview found that Students have morals and ethics related to chemistry, are ready to transfer knowledge and benefits of chemistry, and apply chemical knowledge in choosing consumer goods in their daily lives. The reason is that organizing a board about the structure of chemistry in everyday

life is a review of the texture for yourself and helps your friends understand more about the chemical content. When they understand the structure and types of organic compounds through games, they are motivated to share what they have learned with their friends. The knowledge gained through the game allows them to choose the right products for both consumers and consumer products. As an example of the student›s answer.

"Setting up a board in front of the classroom allows me and my friends to review chemistry knowledge at any time. This allows others who pass by to stop reading and gain more chemistry knowledge. When I played the game, I understood the structure and name of chemistry, which made me want to organize a board to spread chemistry knowledge to my friends." (S03)

"Chemistry is related to daily life, such as liquor, medicine, and organic compounds involved. This makes it useful; we can choose more products. Some products that contain alcohol mixed with alcohol, we cannot buy. Once we have the knowledge, we can consider and make a decision." (S03)

"Our friends do not know about chemistry, so they gain more knowledge of chemistry. Since they want to play games, they want to explain the structure of chemistry to their friends on the class board. Types of organic compounds" (S09)

"Chemistry is related to our lives; we have to encounter many chemicals, and anything useful we can use, such as personal allergy to scotch tape to wound dressing. When I put it on, I get a rash. When we know organic compounds, we know that when we choose to buy the next time, we will be able to buy scotch tape that does not contain that substance." (S09)

According to the results, students had a high average score of attitude towards chemistry after learning through games. This is in a positive direction, in line with Irwanto et al. (2023), who found that using chemistry game applications to organize learning activities with grade 12 students increased students› positive attitudes towards chemistry. This is also consistent with Sailer & Homner (2020), who reported that gamification has a positive effect on affective outcomes, including students' motivation, interest, self-confidence, and attitudes. It aligns with Da Silva Júnior et al. (2022), who found that game elements, such as scoring and reward systems, enhance student motivation and engagement in organic chemistry learning. However, the high overall average scores may suggest that using games alone may not be sufficient; integration with other teaching strategies is necessary to develop attitudes comprehensively across all domains. Part of the reason is that the researcher-developed learning games create challenges and competitions for students, helping them learn independently. The students were excited and active. It helps motivate students to learn (Kanphukiew & Nuangchalerm, 2024; Wahyuni et al., 2025). In addition, it may be due to the nature of the game with strategy, where players must use judgment in making decisions and act within the framework of the rules of the game that must be followed, which is to train students to be within the rules, know how to solve problems, and dare to think and make decisions, which also leads to the psychological development of students (Funa et al., 2021; Erol et al., 2025). The main thing is that the game is interesting. Students learn from their direct, hands-on experience, facilitated by the teacher, so they feel more comfortable understanding than memorizing in class (Lakhonmoon, 2025). In addition, it may be due to the classroom learning atmosphere, which emphasizes support, collaboration, and praise. These factors help students become interested in and encouraged to learn about complex subjects (Khoiri et al., 2023; My et al., 2025). Reinforcement for students is one of the factors that directly affects attitudes. According to Skinner's theory, reinforcement, or reward, occurs when an organism performs the desired behavior. It can help you adjust your behavior or cultivate the desired habits (Mondol et al., 2026). Therefore, it can be concluded that combining a fun learning environment, competition, and positive reinforcement in a domino game focused on organic compounds is crucial for effectively fostering positive attitudes toward chemistry among students and boosting their interest and motivation to learn (Hui & Mahmud, 2023).

This research has several limitations that should be considered when interpreting the results. The sample size was small (n = 19), and data were collected from an Islamic private school, which may limit the generalizability of the findings across different educational contexts. Furthermore, the one-group pretest-posttest design without a control group did not fully control for confounding factors, such as maturation and novelty effects related to the teaching materials. These factors could affect student achievement scores and attitudes. Moreover, the 13-hour limit may be insufficient to assess long-term learning retention and attitudes, especially in chemistry-related ethics and morality, which require a longer development period than other areas. Therefore, future research should use larger sample sizes and more diverse contexts and employ an experimental design with a control group to enhance the reliability and internal validity of the findings.

However, due to the small sample size, purposive sampling, and the absence of a control group, results should be interpreted cautiously and not overgeneralized. Future studies should involve larger, more diverse samples, include a control group, and explore the game's broader effects and its role in promoting equity in science education. The research results suggest that the learning game on organic compounds can help students achieve academic success and develop a positive attitude toward chemistry. Therefore, teachers and students who implement the game should study and understand the steps for playing and the scoring rules. Students should have knowledge and understanding of organic chemistry. This is because the game is a review, and students will only play it after they have learned the organic chemistry content. Understanding chemical structures and reading organic compounds are essential foundations for learning organic chemistry. If the game pieces, which consist of chemical structures and the names of organic compounds, are not understood by the students, the game will not be understood. Teachers must try to explain or provide easy-to-understand examples to help students understand and persist in learning. In addition, teachers in chemistry-related courses can bring learning games. Subject: Organic compounds can be applied to other subjects and can be used to review chemistry knowledge for first-year undergraduate students to prepare the basic chemistry content. Teachers should conduct the learning game after students have been directly taught about organic compounds. This allows the game to reinforce understanding and review knowledge effectively.

Furthermore, the game can be adapted for blended learning environments or as a formative assessment tool. The research results show that students who learn using a learning game on organic compounds have an average post-school achievement score that is statistically significantly higher than their pre-school score at the .05 level, so other variables, such as learning persistence, should be studied to support students' learning through games. When considering the effect of attitude toward chemistry, students' attitudes were positive, suggesting that games could improve them. Science learning games should be developed on other topics, such as chemical bonds, elements, and molecular mass calculations, to help students gain knowledge and understanding of chemistry while also making learning fun.

Furthermore, the learning game the researcher created can only be used in the classroom due to its resource requirements, as students need to study all four sets of organic compounds. Thus, we could modify it into a learning game application. In addition to allowing students studying organic compounds to take examinations in each subject at any time, anywhere, without restrictions, this will enable them to practice and review the names, chemical structures, and functional groups of each organic compound. The sample group should be expanded to include multiple schools and diverse types, both public and private, to ensure the broader applicability of the research findings. In addition, a digital or online version of the domino game should be developed to increase accessibility and flexibility of use. Finally, comparative research on the effectiveness of dominoes relative to other teaching aids should be conducted to identify the most suitable approach for teaching organic compounds.

CONCLUSION

The learning game's efficiency was 78.95/80.79, exceeding the established criterion of 75/75. Students who were taught using a learning game showed a significantly higher average academic achievement score after school and a positive attitude toward chemistry. This research suggests that the developed game may serve as a promising teaching tool for challenging content and that students showed improvements in both the cognitive and affective domains after game-based learning. A key contribution of this research is that it builds on previous work at new grade levels and provides a ready-to-use chemistry teaching tool. The study's learning game shows potential to engage students, improve achievement, and foster positive attitudes toward chemistry.

REFERENCES

Adipat, S., Laksana, K., Busayanon, K., Asawasowan, A., & Adipat, B. (2021). Engaging students in the learning process with game-based learning: The fundamental concepts. *International Journal of Technology in Education*, *4*(3), 542–552.

Akour, M., Alsghaier, H., & Aldiabat, S. (2020). A game-based learning approach to improve self-learning among motivated students. *International Journal of Technology Enhanced Learning*, *12*(2), 146–160.

Almeida, B., Santos, M., & Justi, R. (2023). Aspects and abilities of science literacy in the context of nature of science teaching. *Science & Education*, *32*(3), 567–587.

Anantanukulwong, R., Chiangga, S., & Pongsophon, P. (2023). Funds of knowledge in Muslim culture in the southern border provinces of Thailand for culturally responsive physics education. *Cultural Studies of Science Education*, *18*(3), 791-807.

Arlinwibowo, J., Ishartono, N., Linguistika, Y., Purwoko, D., & Suprapto, S. (2023). Gamification in the STEM domain subject: The prospective method to strengthen teaching and learning. *Jurnal Pendidikan IPA Indonesia*, *12*(4), 564-574.

Ayae, A., & Savski, K. (2024). Echoes of the past, hopes for the future: Examining temporalised schoolscapes in a minority region of Thailand.

International Journal of Multilingualism, *21*(3), 1349-1368.

Badillo, D. F., Noriega-Usi, A., Reina, A., & Reina, M. (2026). Salt Wars: A Card Game To Learn Inorganic Chemistry Nomenclature. *Journal of Chemical Education*, *103*(1), 685-692.

Bergman, J. (1996). *Understanding educational measurement and evaluation*. Boston: Houghton Mifflin.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain*. New York: David McKay.

Boghian, I., & Cojocariu, V. M. (2023). Using games to build social emotional learning skills. *Revista Romaneasca pentru Educatie Multidimensionala*, *15*(1), 622–656.

Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer.

Brahmawong, C. (2013). Developmental testing of media and instructional package. *Silpakorn Educational Research Journal*, *5*(1), 1–20.

Bulut, D., Samur, Y., & Cömert, Z. (2022). The effect of educational game design process on students' creativity. *Smart Learning Environments, 9*(1), 1–15.

Byusa, E., Kampire, E., & Mwesigye, A. R. (2022). Game-based learning approach on students' motivation and understanding of chemistry concepts: A systematic review of literature. *Heliyon*, *8*(5), 1-10.

Chen, S., Husnaini, S. J., & Chen, J. J. (2020). Effects of games on students' emotions of learning science and achievement in chemistry. *International Journal of Science Education, 42*(13), 2224–2245.

Chen, S. Y., & Chu, S. Y. (2020). Using augmented reality to experiment with elements in a chemistry course. *Computers in Human Behavior*, *111*, 106418.

Churngchow, C., & Sinprajukpol, W. (2016). Factors affecting the scholastic achievement of Prince of Songkla University students from private schools with Islam instruction in the three southern border provinces. *Kasetsart Journal of Social Sciences, 37*(1), 59–65.

Chu, S. T., Hwang, G. J., Chien, S. Y., & Chang, S. C. (2023). Incorporating teacher intelligence into digital games: An expert system guided self-regulated learning approach to promoting EFL students' performance in digital gaming contexts. *British Journal of Educational Technology*, *54*(2), 534–553.

Cohen, L., Manion, L., & Morrison, K. (2000). *Research methods in education* (5th ed.). London: Routledge.

Council of University Presidents of Thailand. (2023). *Thai University Central Admission System (TCAS).* Bangkok: CULearn.

Cronbach, L. J. (1990). *Essentials of psychological testing* (5th ed.). New York: Harper Collins.

Crucho, C. I., Gomes, M. J., & Avó, J. (2025). A role-playing tabletop game on laboratory techniques and chemical reactivity: a game-based learning approach to organic chemistry education. *Chemistry Teacher International*, *7*(3), 455-470.

Da Silva Júnior, J. N., Castro, G. D. L., Melo Leite Junior, A. J., Monteiro, A. J., & Alexandre, F. S. O. (2022). Gamification of an entire introductory organic chemistry course: A strategy to enhance the students' engagement. *Journal of Chemical Education*, *99*(2), 678–687.

Demirkiran, M. C., & Tansu Hocanin, F. (2021). An investigation on primary school students' dispositions towards programming with game-based learning. *Education and Information Technologies*, *26*(4), 3871–3892.

Dood, A. J., & Watts, F. M. (2022). Students' strategies, struggles, and successes with mechanism problem solving in organic chemistry: A scoping review of the research literature. *Journal of Chemical Education, 100*(1), 53–68.

Erol, A., Saracaloğlu, A. S., & Dinçer, B. (2025). The Role of Mind and Intelligence Games in Supporting Student Development: A Focus on Cognitive, Affective, and Psychomotor Domains. *Education & Youth Research*, *5*(1), 92-112.

Feng, J., Tan, W. H., & Yu, B. (2024). A systematic literature review of the impact of gamification instruction on students' problem-solving skills. *Int J Eval & Res Educ ISSN*, *2252*(8822), 4083.

Ferguson, G. (1981). *Statistical analysis in psychology and education*. New York : McGraw-Hill.

Flores-Aguilar, G., Prat-Grau, M., Fernández-Gavira, J., & Muñoz-Llerena, A. (2023). "I learned more because I became more involved": Teacher's and students' voice on gamification in physical education teacher education. *Environmental Research and Public Health*, *20*(4), 3038.

Franco-Mariscal, A. J., Oliva-Martínez, J. M., Blanco-López, Á., & España-Ramos, E. (2016). A game-based approach to learning the idea of chemical elements and their periodic classification. *Journal of Chemical Education*, *93*(7), 1173–1190.

Funa, A. A., Gabay, R. A. E., & Ricafort, J. D. (2021). Gamification in genetics: Effects of gamified instructional materials on the STEM students' intrinsic motivation. *Jurnal Pendidikan IPA Indonesia*, *10*(4), 462-473.

Gupte, T., Watts, F. M., Schmidt-McCormack, J. A., Zaimi, I., Gere, A. R., & Shultz, G. V. (2021). Students' meaningful learning experiences from participating in organic chemistry writing-to-learn activities. *Chemistry Education Research and Practice*, *22*(2), 396–414.

Hermanns, J., Bresler, A., & Kunold, H. (2023). Students' learning and application of basic concepts in the course "Organic Chemistry I for Preservice Chemistry Teachers". *Journal of Chemical Education*, *100*(11), 4249–4260.

Hu, Y., Gallagher, T., Wouters, P., Van Der Schaaf, M.,

& Kester, L. (2022). Game-based learning has good chemistry with chemistry education: A three-level meta-analysis. *Journal of Research in Science Teaching*, *59*(9), 1499-1543.

Hui, H. B., & Mahmud, M. S. (2023). Influence of game-based learning in mathematics education on the students' cognitive and affective domain: A systematic review. *Frontiers in psychology*, *14*, 1-15.

Institute for the Promotion of Teaching Science and Technology (IPST). (2002). *The manual of science evaluation*. Bangkok: Curusapha Ladphoa.

Irwanto, I., Afrizal, A., Lukman, I. R., Agung, D., & Wijayako, R. S. (2023). Go-Chemist! app and its impact on students' attitudes toward chemistry. *TEM Journal*, *12*(3), 1638.

Kavak, N., Yamak, H., & Togru, H. (2021). Organosliding game: Organic compounds maker. *Journal of Chemical Education, 98*(8), 2596–2602.

Kanphukiew, S., & Nuangchalerm, P. (2024). Enhancing scientific problem-solving and learning achievement of lower secondary students through active learning management. *Jurnal Pendidikan IPA Indonesia*, *13*(1), 172-181.

Khoiri, N., S. Ristanto, & A. F. Kurniawan. (2023). Project-based learning via traditional game in physics learning: Its impact on critical thinking, creative thinking, and collaborative skills. *Jurnal Pendidikan IPA Indonesia*, *12*(2), 286-292.

Kochkarova, R. R., & Turgunov, E. (2023). Improving the methodology of teaching chemistry lessons at school with the help of different games. *American Journal of Applied Science and Technology*, *3*(10), 15–19.

Korkmaz, S., Cetin-Dindar, A., & Oner, F. K. (2023). Impact of educational game development on students' achievement and attitudes toward science. *The Journal of Educational Research*, *116*(5), 268-279.

Lakhonmoon, T., Rutanatarntong, Y., & Noisombut, T. (2025). Developing the Kid-Bright board for controlling lamps and fans as game-based learning for twelfth-grade students. *Journal of Education and Learning (EduLearn)*, *19*(2),1074–1082.

Lateh, A., Thongsuk, J., Machae, D., Masae, A., Lateh, A., Khongpheng, N., & Pooteh, R. (2025). Islamic Private Schools in Southern Thailand: Prospects and Future Management Models. *Educational Process: International Journal*, *19*, e2025583.

Li, C.-T., Hou, H.-T., & Lin, W.-S. (2022). Chemistry education board game based on cognitive mechanism: Multi-dimensional evaluation of learners' knowledge acquisition, flow and playing experience of board game materials. *Research in Science & Technological Education*, *42*(3), 699–719.

Lutfi, A., Aftinia, F., & Permani, B. E. (2023). Gamification: Game as a medium for learning chemistry to motivate and increase retention of students' learning outcomes. *Journal of Technology and Science Education*, *13*(1), 193–207.

Martinez Sainz, G., Ioannidou, O., Pignoloni, F., Stainforth, K., Rebel, M., Sousa de Sena, Í., & Cocco, C. (2026). Game-based learning as a pedagogical tool towards climate change learning and participation. *Oxford Review of Education*, *52*(2), 255-280.

McGriff, S. J. (2000). *Instructional system design (ISD): Using the ADDIE model*. College of Education: Penn State University.

Miguel-Gómez, J. E., Salazar, D., & Reina, M. (2023). Intermolecular forces dominoes! A game for aiding students in their revision of intermolecular forces. *Journal of Chemical Education*, *100*(5), 1895–1904.

Ministry of Education Thailand. (2008). *Basic education core curriculum B.E. 2551 (A.D. 2008)*. Bangkok: Kurusapa Ladprao Publishing.

Mondol, M., Rahul, M. M., & Hasan, M. J. (2026). Perceived Role of Positive Reinforcement on Primary Students' Academic Engagement and Motivation. *Asian Journal of Education and Social Studies*, *52*(3), 117-132.

Musengimana, J., Kampire, E., & Ntawiha, P. (2021). Factors affecting secondary schools students' attitudes toward learning chemistry: A review of literature. *EURASIA Journal of Mathematics, Science and Technology Education*, *17*(1). 1-12.

My, N. L. H., Phuong, U. M. H., & Kim, A. N. T. (2025). Students' collaborative performance through STEM topic "Led Card–Light It Up" for 8th grade. *Jurnal Pendidikan IPA Indonesia*, *14*(1), 83-92.

National Institute of Educational Testing Service (NIETS). (2024). *Report on the results of the Ordinary National Educational Test (O-NET)*. Bangkok: National Institute of Educational Testing Service.

Nieto-Escamez, F. A., & Roldán-Tapia, M. D. (2021). Gamification as online teaching strategy during COVID-19: A mini-review. *Frontiers in Psychology*, *12*, 1-9.

Nuha, F. H., & Purwanti, K. Y. (2023). The effect of game-based learning assisted by fun card puzzle on the conceptual understanding of class 5th elementary school students. *International Journal of Scientific Multidisciplinary Research*, *1*(5), 527–538.

Othman, M. K., Mat, R., & Sim, K. C. (2025). A systematic review of paper-based and digital board games for collaborative science learning. *Review of Education*, *13*(3), 1-53.

Phajan, T., Cojorn, K., & Dien, T. N. N. (2025). Exploring the Representational Competence of Eleventh-Grade Students on the Rates of Chemical Reactions. *Jurnal Pendidikan IPA Indonesia*, *14*(2), 351-363.

Prasertsin, U. (2020). *Research instruments in education and social sciences*. Bangkok: Chulalongkorn University.

Pratomo, H., Fitriyana, N., Wiyarsi, A., & Marfuatun, M. (2025). Mapping chemistry learning difficulties of secondary school students: a cross-grade study. *Journal of Education and Learning (EduLearn)*, *19*(2), 909-920.

Reina, A., Garcia-Ortega, H., Gracia-Mora, J., Marin-Becerra, A., & Reina, M. (2022). Compounds and molecules: learning how to distinguish them through an educational game. *Journal of Chemical Education*, *99*(3), 1266-1271.

Rubba, P. A., & Andersen, H. O. (1978). Development of an instrument to assess secondary school students' understanding of the nature of scientific knowledge. *Science Education*, *62*(4), 449–458.

Rudolph, J. L. (2024). Scientific literacy: Its real origin story and functional role in American education. *Journal of Research in Science Teaching*, *61*(3), 519–532.

Sah, M. K., Ettarhouni, Z. O., Pathak, R., Gawad, J., Bonde, C., Arya, S. P., & Bhattarai, A. (2025). Green chemistry: Strategies and sustainable approaches for bridging UN SDGs. *ChemistrySelect*, *10*(25), e202500847.

Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. *Educational Psychology Review*, *32*(1), 77–112.

Saithongdee, A., & Sirirat, T. (2024). Learning mole calculation through a board game in an engaging and enjoyable environment: Design, implementation, and evaluation. *Journal of Chemical Education*, *101*(4), 1551–1563.

Schreier, M. (2012). *Qualitative content analysis in practice*. London: Sage.

Srisaard, B. (2017). *Principles of research*. (10th ed.). Bangkok: Surivitayasarn.

Stammes, H., Henze, I., Barendsen, E., & de Vries, M. (2023). Characterizing conceptual understanding during design-based learning: Analyzing students' design talk and drawings using the chemical thinking framework. *Journal of Research in Science Teaching, 60*(3), 643–674.

Taber, K. S. (2020). Conceptual confusion in the chemistry curriculum: Exemplifying the problematic nature of representing chemical concepts as target knowledge. *Foundations of Chemistry, 22*(2), 309–334.

Teo, J., Sharma, P., Kon, M. W. R., Han, J. Y., Tan, T. L. Y., Teh, Y. L., Yap, J., Lam, Y., & Fung, F. M. (2025). Changing attitudes toward organic chemistry via a digital multiplayer game. *Journal of Chemical Education*, *102*(4), 1476–1491.

UNESCO. (2021). *Reimagining our futures together: A new social contract for education*. Paris: UNESCO Publishing.

United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. UN General Assembly. Retrieved from https://sdgs.un.org/2030agenda

Vasinayanuwatana, T., Ketsing, J., Pongsophon, P., & Chattham, N. (2019). Challenges in science teaching in Islamic private schools in southern Thailand. *Journal of Education Prince of Songkla University*, *30*(1), 97–110. https://so02.tci-thaijo.org/index.php/jam/article/view/284076

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wang, Y., Rocabado, G. A., Lewis, J. E., & Lewis, S. E. (2021). Prompts to promote success: Evaluating utility value and growth mindset interventions on general chemistry students' attitude and academic performance. *Journal of Chemical Education*, *98*(5), 1476–1488.

Wanaeloh, W., Zetra, A., & Putri, I. A. (2024). Dynamics of local Melayu language wisdom and social changes in 3 provinces: Yala, Pattani, Narathiwat, and Southern border provinces of Thailand. *Eduvest-Journal of Universal Studies*, *4*(12), 11712-11726.

Wahyuni, F., Hidayah, N., Ramli, M., Hutasuhut, I. J., Hanafi, H., Kurniawan, N. A., & Putri, S. N. J. (2025). The effect of bingo-KDK game to improve preservice counselor communication skills. *Journal of Education and Learning (EduLearn)*, *19*(3), 1288–1294.

Wardani, S., Lindawati, L., & Kusuma, S. B. W. (2017). The development of inquiry by using android-system-based chemistry board game to improve learning outcome and critical thinking ability. *Jurnal Pendidikan IPA Indonesia*, *6*(2), 196-205.

Wiyarsi, A., Pratomo, H., & Priyambodo, E. (2020). Vocational high school students' chemical literacy on context-based learning: A case of petroleum topic. *Journal of Turkish Science Education*, *17*(1), 147–161.

Yu, Z., Gao, M., & Wang, L. (2021). The effect of educational games on learning outcomes, student motivation, engagement and satisfaction. *Journal of Educational Computing Research, 59*(3), 522–546.

Yusuf, I., & Thongin, A. (2025). The role of Islamic education in building of Islamic public value of multicultural citizenship in southern Thailand. In *Islamic Public Value* (pp. 281-307). Edward Elgar Publishing.

Zeng, J., Parks, S., & Shang, J. (2020). To learn scientifically, effectively, and enjoyably: A review of educational games. *Human Behavior and Emerging Technologies*, *2*(2), 186–195.