SEAT

ISSN: 2821-9163 (Online)

International Journal of Science Education and Teaching

IJSET

IJSET Vol.4 No. 2
(May - August 2025)

Published by
The Science Education Association (Thailand)

International Journal of Science Education and Teaching
Vol. 4, No. 2 (May – August 2025)

ABOUT IJSET

International Journal of Science Education and Teaching (IJSET) is supported by Science Education Association (Thailand) or SEAT. IJSET seeks articles addressing issues including science education, physics education, chemistry education, biology education, technology education, STEM education, science teacher education, early childhood science education, science curriculum and instruction, and other related science educational fields.

Peer Review Process

Articles submitted for publication must never have been previously published or currently under review at another journal. Each paper is reviewed by the editor and, if it is judged suitable for this publication, it is then sent to at least two independent reviewers for double blind peer review. Based on their recommendation, as well as consultation between relevant Editorial Board members the editors then decides whether the paper should be accepted as is, revised or rejected.

Publication Frequency

The IJSET provides an academic platform for work in the fields of interdisciplinary education. The IJSET publishes 3 issues annually. These include:

- Issue 1 (January - April)
- Issue 2 (May - August)
- Issue 3 (September - December)

Issue: IJSET Vol. 4 No. 2 (May – August 2025)
Publication Date: August 30, 2025
Publisher: Science Education Association (Thailand)

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

IJSET EDITORIAL TEAM

Editors

Assoc. Prof. Dr. Chokchai Yuenyong	Khon Kaen University, Thailand
Assoc. Prof. Dr. Prasart Nuangchalerm	Mahasarakham University, Thailand
Assoc. Prof. Dr. Saksri Supasorn	Ubon Ratchathani University, Thailand
Assist. Prof. Dr. Chanyah Dahsah	Srinakharinwirot University, Thailand

Editorial Board

Prof. Dr. P John Williams	Curtin University, Australia
Prof. Dr. Peter C Taylor	Murdoch University, Australia
Prof. Dr. Toshinobu	Hatanaka Toho University, Japan
Prof. Dr. Chun-Yen Chang	National Taiwan Normal University, Taiwan
Prof. Dr. Young-Shin Park	Chosun University, Gwangju, Korea
Prof. Dr. Lilia Halim	Universiti Kebangsaan Malaysia
Prof. Dr. Hadi Suwuno	State University of Malang, Indonesia
Prof. Dr. Suratno	University of Jember, Indonesia
Prof. Dr. Manuel Barquilla	Mindanao State University - Iligan Institute of Technology, Philippines
Assoc. Prof. Dr. Cathy Buntting	University of Waikato, New Zealand
Assoc. Prof. Dr. Duc Nguyen Mau	Hanoi University of Education, Vietnam
Assoc. Prof. Dr. Nason Phonpok	Srinakharinwirot University, Thailand
Assoc. Prof. Dr. Pongprapan Pongsophon	Kasetsart University, Thailand
Assoc. Prof. Dr. Suthida Chamrat	Chaing Mai University, Thailand
Assist. Prof. Dr. Pattamaporn Pimthong	Kasetsart University, Thailand
Assist. Prof. Dr. Theerapong Sangpradit	Srinakharinwirot University, Thailand
Assist. Prof. Dr. Chaninan Pruekpramool	Srinakharinwirot University, Thailand
Assist. Prof. Dr. Phasarabet Wetwiriyasakul	Thaksin University, Thailand
Assist. Prof. Dr. Siriwan Chatmaneerungcharoen	Phuket Rajabhat University, Thailand
Assist. Prof. Dr. Panwilai Dokmai	Mahasarakham Rajabhat University, Thailand
Dr. Adchara Chaisri Khureerung	Sakon Nakhon Rajabhat University, Thailand
Dr. Warangkhana Thongnoppakun	Phuket Rajabhat University, Thailand
Dr. Suriya Chapoo	Naraesuan University, Thailand
Dr. Jiraporn Tupsai	Khon Kaen University, Thailand
Dr. Pratuengsook Maneelam	Khon Kaen University, Thailand
Dr. Sukanya Sutaphan	Khon Kaen University, Thailand
Dr. Ruhaisa Dearamae	Yala Rajabhat University, Thailand

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

TABLE OF CONTENTS

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

International Journal of Science Education and Teaching
Vol. 4, No. 2, pp. 64-76, May. – Aug. 2025
http://doi.org/10.14456/ijset.2025.05

The Development of Grade 3 Students' Collaboration and Teamwork Competency Using STEM Inquiry-Based Learning

Suthasinee Thanomsat[1], Nongnoot Wongngao[2], Pattamaporn Pimthong[1*]
[1]*Faculty of Education, Kasetsart University, Thailand*
[2]*Sena Nikhom School, Thailand*
*Email: fedupppi@ku.ac.th

Received: 10 Apr. 2025 Revised: 13 May 2025 Accepted: 15 May 2025

Abstract. This classroom action research aimed to study the best practices in developing collaboration and teamwork competency of 23 Grade 3 students through STEM inquiry-based learning. Data were collected from collaboration and teamwork competency assessment forms, teacher logs, and artifacts. Data were grouped according to the collaboration and teamwork competency level criteria. The research result found that students had higher collaboration and teamwork competency in all components, namely, being good members and leaders (15 students) showed level 3 in testing prototype, collaborative work process (20 students) showed level 3 in redesigning, and relationship building and conflict management (16 students) showed level 3 in redesigning. In addition, two good practices were found: integration between the design process and the key characteristics of inquiry to promote collaboration and teamwork competency and using probing questions to help students explore and collect empirical evidence to design artifacts through the design process.

Keywords: STEM inquiry-based learning, Collaboration and Teamwork Competency, STEM Education

INTRODUCTION

The first researcher is a teacher for Grade 3 students at a small school under the jurisdiction of the Bangkok Metropolitan Administration. She found that when working in groups, her students did not understand their roles and responsibilities, and some failed to seek input from their peers. As a result, the assigned tasks were often incomplete within the allocated time due to a lack of teamwork skills necessary for achieving shared goals. She tried to find ways to help her students improve collaboration and teamwork. However, in addition to teamwork challenges, the researcher observed that students struggled with conceptualizing how wind can be harnessed as an energy source. Moreover, textbooks often present wind energy in an abstract manner, lacking hands-on experiences that connect scientific concepts with tangible outcomes and real-life applications. The researchers implemented STEM inquiry-based learning to tackle the conceptual challenges in understanding wind generation and to enhance collaboration. This instructional approach integrates the essential features of scientific inquiry with the engineering design process, extending scientific explanations to solve real-world problems through STEM activities (Pimthong, 2023).

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

STEM inquiry-based learning integrates the core features of scientific inquiry with the design process. It extends scientific explanations toward solving real-world problems through the STEM approach (Pimthong, 2023). For instance, the study by Nilubon (2022) found that STEM inquiry-based learning enhances students' teamwork competencies by encouraging knowledge exchange among classmates and promoting collaborative activities involving analysis, discussion, questioning, and decision-making for solving situational problems. This aligns with research by Khamta et al. (2023), which showed that STEM inquiry-based learning helps students solve real-life problems by applying familiar knowledge to create products through creative problem-solving.

Furthermore, STEM education benefits primary students by fostering essential 21st-century skills (King & English, 2016). For instance, research by Samahito (2015) demonstrated that STEM education in early childhood supports development across various domains, equipping children with vital foundational skills for future learning. STEM education emphasizes classroom instruction and the promotion of STEM literacy in individuals. Through design processes, STEM learning integrates four disciplines—science, technology, engineering, and mathematics. This integration provides students with critical knowledge and skills necessary for contemporary life and the future. Among the various STEM learning approaches, STEM inquiry-based learning specifically combines the design process with key characteristics of inquiry (Pimthong, 2023; Nilubon, 2022). This study aims to identify effective practices for developing collaboration and teamwork competency in Grade 3 primary school students through STEM inquiry-based learning and to evaluate the collaboration and teamwork abilities of Grade 3 students.

RESEARCH QUESTIONS

1. What are the good practices for developing collaboration and teamwork competency in Grade 3 primary school students through STEM inquiry-based learning?
2. How does STEM inquiry-based learning enhance the collaboration and teamwork competency of Grade 3 students?

METHODOLOGY

This classroom action research was conducted using the conceptual framework of Kemmis and McTaggart (1998), which involves the development of teaching and learning from the first cycle to the new cycle to establish a solid learning management approach in each cycle (PAOR). This process consists of four steps: (1) the planning stage, (2) the implementation stage, (3) the observation stage, and (4) the reflection stage. The researchers conducted five cycles based on five lesson plans. While the PAOR framework guided the iterative improvement of teaching and learning, each cycle also explicitly integrated the five essential features of scientific inquiry namely, Engaging in scientifically oriented questions, Giving priority to evidence, Formulating explanations based on evidence, Evaluating explanations in connection with scientific knowledge, and Communicating explanations (National Research Council, 2000) integrated with the components of the design process, including Identify needs/problems, Research, Select an appropriate solution, Generate or develop the best solution, Create a prototype Test the prototype, Evaluate/Reflect and Improve (Pimthong, 2023). The researchers adapted eight activities of the STEM inquiry-based learning from Nilubon (2022), namely,

1. Identify needs/problems: Identify needs or define problems in a given context or situation. Learners participate by asking scientific questions and focusing on evidence that helps develop and evaluate explanations that answer scientific questions.
2. Research: Collect data and investigate the needs or problems studied. Learners focus on evidence that helps develop and evaluate explanations that answer scientific questions.
3. Suggest approaches: Learners generate multiple approaches to meet needs or solve problems. They evaluate their explanations by reflecting on their scientific understanding and communicating and justifying their explanations with their findings.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

4. Select an appropriate solution: Generate or develop the best solution to meet needs or solve problems. Learners evaluate their explanations by reflecting on their scientific understanding.
5. Create a prototype: To meet needs or solve problems, generate a prototype of a selected solution by creating an explanation based on evidence that answers scientific questions. Learners evaluate their explanations by reflecting on their scientific understanding.
6. Test the prototype: This test determines whether the prototype of the selected solution can meet the need or solve the problem, and how, using the evidence to answer the scientific question and evaluating the explanation based on scientific understanding.
7. Evaluate/Reflect: This involves evaluating, reflecting on, or providing feedback on the prototype test to determine whether it meets the need or solves the problem, and whether it is appropriate to continue using it. It is done by creating an explanation from the evidence used to answer the scientific question, communicating the explanation, and giving reasons for it related to the discovery.
8. Improve: Improvement occurs after implementation to meet needs or solve problems as effectively as possible. The learner highlights evidence that will aid in developing and evaluating the explanation.

Participants

The participants were 23 third-grade students from a small school in Bangkok, comprising nine males and 14 females, in a classroom where the first researcher was responsible for teaching.

This research, conducted during the first author's teaching practicum, received approval from the school and parental consent. Although IRB approval was not required, the study was supervised by a mentor teacher and a university supervisor to ensure ethical standards were upheld.

Research Tools

1. There are five lesson plans (nine hours) on "Wind Generation," which include Lesson Plan 1: Carp Flags Can Float; Lesson Plan 2: Wind Helps Carp Flags Float; Lesson Plan 3: Directional Airbags Design Sketch; Lesson Plan 4: Prototype of Directional Airbags; and Lesson Plan 5: Adjust a Little Bit to Conquer the Finish Line. The lesson plan and tools used for data collection through quality inspection by a university supervisor, a mentor teacher, and three experts.
2. Data collection tools include:
   2.1 The Collaboration and Teamwork Competency Assessment Form was designed to assess students' observable behaviors during STEM inquiry-based activities. It employed a structured rubric based on OBEC's (2021) three-level competency framework: Level 1 (Beginner), Level 2 (Developing), and Level 3 (Able), namely,
   - Level 1: Know their roles and responsibilities, be committed to their activities, and collaborate with others to achieve success according to agreements and regulations. Express themselves appropriately in various situations as per instructions.
   - Level 2: Know and take responsibility for their roles, have confidence in completing various steps, and adhere to the instructions and rules of the team. When receiving guidance to support activities with others for success, recognize the feelings of others and respond to different situations according to the instructions.
   - Level 3: Take responsibility and leverage their strengths to complete tasks. Enjoy working. Be a team member who engages in decision-making, goal setting, agreement-making, and teamwork. Demonstrate understanding to teammates with friendliness, as recommended.

The rubric score included descriptors for evaluating students' abilities to share responsibilities, contribute ideas, lead and support peers, and resolve conflicts during teamwork. Evaluations were conducted by the first researcher and confirmed with a university supervisor and a mentor teacher at the end of each cycle.

   2.2 The teacher logs for the 1st researcher to record various events during teaching hours, reflections on teaching performance, and the problems and obstacles that arose in the classroom, which will be used to develop and enhance learning activities for the next time.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

2.3 Student artifact assessment form and activity sheets

Data Collection

Data collection in this study employed multiple instruments to ensure comprehensive insights into students' collaboration and teamwork competency (Table 1). The researchers used teacher logs to record observations and personal learning from each teaching session to identify effective instructional design practices. Additionally, feedback from a university supervisor and a mentor teacher was gathered after each implementation to inform the best practices further. Moreover, students' artifact assessments and activity worksheets were reviewed to further prove evidence of their collaborative abilities.

Data Analysis

To address Research Question 1, the researchers employed a thematic analysis approach (Braun and Clarke, 2006). Data from teacher logs and feedback from the university supervisor and mentor teacher were read multiple times to ensure deep familiarity. Manual open coding was conducted to assign initial codes to meaningful text segments. These codes were then grouped into broader categories, from which key themes were developed. Relationships among themes were examined to identify patterns in instructional practices that supported students' collaboration and teamwork competency. Two best practices were synthesized from this process. Direct quotes were used to substantiate these themes. These external insights, combined with conversational evidence from the teacher logs (e.g., student dialogues and observations), helped to crystallize the best practices. The emerging themes were verified through peer debriefing with the mentor teacher and university supervisor to enhance trustworthiness. Their feedback was used to refine interpretations and confirm the validity of the final themes.

Table 1: Data collection and analysis.

Research Question	Instruments	Data Collection	Data Analysis
1. What are the good practices for developing collaboration and teamwork competency in Grade 3 primary school students through STEM inquiry-based learning?	Teacher Logs	The 1st researcher recorded reflections and observations after each teaching session to document what occurred and what was learned.	The teacher logs were thoroughly reviewed to identify key themes using thematic analysis.
	A university supervisor and a mentor teacher evaluation	Feedback from a university supervisor and a mentor teacher was collected after each teaching session.	Feedback was used to validate and enrich interpretations.
2. How does STEM inquiry-based learning enhance Grade 3 students' collaboration and teamwork competency?	Collaboration and teamwork competency assessment	Students completed the assessment after each session.	Data were categorized according to collaboration and teamwork competency levels defined by OBEC (2021).
	Student artifact assessments and activity worksheets	Student work and worksheets were collected and reviewed to provide evidence of their collaborative abilities.	Student work was analyzed and categorized according to collaboration and teamwork competency levels defined by OBEC (2021).

For Research Question 2, the results from student assessments and evaluations of students' work were categorized according to the collaboration and teamwork competency levels defined by the Office of the Basic Education Commission (OBEC, 2021). This allowed for a structured analysis of each student's development in teamwork skills.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

RESULTS AND DISCUSSION

Findings for Research Question 1

There are two best practices, namely integrating the design process with inquiry-based learning and the using of probing questions.

Best Practice 1: Integrating Design Process with Inquiry-Based Learning

The first best practice identified was integrating the design process with key features of inquiry-based learning. This approach was found to promote students' collaboration and teamwork competency.

Lesson Plan 1: The Flying Koinobori

In the first lesson, students were introduced to airbags as directional indicators. The researcher grouped students heterogeneously and had them observe a video titled "Chasing the Koinobori Flag" to activate prior knowledge and stimulate inquiry. Students were engaged through scientific questioning and were encouraged to justify their explanations, although some were less participatory.

Students were tasked with acting as engineers to design effective directional airbags for pilots. Through tests involving various locations to make the koinobori fly, students generated explanations based on evidence and linked them to prior experiences. Due to differing experience levels, some students struggled to express their ideas, prompting the researcher to utilize diverse media, namely images, videos, and presentations, to enhance engagement. From the first lesson plan, the researchers understood that group work and inquiry-based activities fostered collaborative learning and contributed to students' prior knowledge, which aligned with the feedback from the university supervisor: *"You should demonstrate the specific student performance that reflects collaboration and teamwork during STEM inquiry-based activities."* Thus, in the next lesson, the researchers concentrated on how students participate in STEM inquiry-based activities.

Lesson Plan 2: Wind Helps the Koinobori Fly

Students participated in an inquiry activity involving video observation and an experiment on how wind is generated (Paper Spinning Snack). They were prompted with questions such as:

Researcher: What was the paper like before the candle was introduced?
Student 06: The paper didn't move.
Researcher: What happened after the candle was lit?
Student 13: The paper started spinning.
Researcher: Why do you think the paper moved?
Student 14: Because the wind made it move.

Students collaboratively summarized design specifications and demonstrated an understanding of their roles within the team. They engaged positively in various scenarios, indicating strong teamwork and shared ownership of group tasks.

Lesson Plan 3: Directional Airbag Design Sketch

Each group selected materials to design the directional airbags. Students actively answered questions and shared their opinions based on prior experience. The researcher used probing questions to stimulate creative and critical thinking, such as:

Researcher: What materials did your group choose for the directional airbag design and why?
Group 1: Material 1 because the fabric is durable.
Group 2: Material 3 because plastic is waterproof.

Students collaboratively illustrated and wrote about their design ideas. Roles were assigned within each group. This collaborative effort resulted in the successful design of products, showcasing the students' ability to work cooperatively and share responsibilities. Figure 1 shows the students' completed design sketches from the collaborative working process.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Figure 1: Worksheet 3 design sketch

Lesson Plan 4: Directional airbags Prototype

Students became more aware of their roles and responsibilities, collaborating stepwise toward a shared goal. They tested their directional airbag prototypes in different locations and documented their observations. Each team participated in the decision-making process to select the best solution and design, as illustrated in Figure 2 and the dialogue.

Figure 2: Prototypes

Researcher: Where did your prototype successfully fly?

Group 2: In front of fan settings 1 and 3 and at the front of the classroom.

Researcher: Why do you think it flew there?

Group 3: Because there was wind in the area.

Each student contributed based on their strengths, such as drawing, coloring, and writing. All group members made efforts to support one another toward a successful outcome.

Lesson Plan 5: Final Adjustments

Students brainstormed the strengths and limitations of their prototypes and then proposed design improvements. For example, as illustrated in Figure 3 and the dialogue:

Researcher: How would you improve your directional airbag?

Group 1: Use plastic, add more layers, and outline with black lines.

Researcher: Why these changes?

Group 1: Plastic is waterproof; more layers make it stronger, and black lines make it look better.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Figure 3: Redesign directional airbags of Group 1

Students engaged in reflective discussions, expressing ideas verbally and visually. They worked together to address limitations and improve their designs.

Best Practice 2: Use of Probing Questions

The second-best practice involved asking probing questions to help students gather evidence and create designs throughout the design process.

Lesson Plan 1: The Flying Koinobori

The researcher used probing questions to stimulate curiosity and assist students in exploring scientific explanations. This encouraged them to question, experiment, and connect new knowledge with prior learning. As illustrated in the following conversation:

Researcher: In which areas do your koi flags float or move?

Student 02: The balcony in front of the room and in front of the fan

Researcher: What do you believe allows these areas to make the koinobori flags float or move?

Student 04: Because there is wind

Researcher: What is wind?

Student 03: Air moves from one place to another

Researcher: Why do you think air moves from one place to another? What reasons do you believe contribute to this?

The researcher found that asking questions starting with “why” stimulated curiosity, prompting students to inquire and seek answers through their experiments or knowledge. This enabled students to connect new knowledge with what they had previously learned.

Lesson Plan 2: Wind Helps the Koinobori Fly

Before experimenting with wind generation, students were prompted with probing questions to stimulate their reasoning. Consequently, they actively gathered and evaluated evidence to support scientific claims. In the following conversation:

Researcher: What did the paper candle look like before?

Student 23: The paper stopped moving.

Researcher: What did the paper candle look like after?

Student 21: The paper spun back and forth.

Researcher: Why do you think the paper moves back and forth?

Student 14: Because the wind makes the paper spin back and forth.

The researcher sparked the students' curiosity, prompting them to ask questions that led them to seek answers through scientific explanations grounded in empirical evidence. The students collaborated, brainstormed, and navigated the design process to create the artifacts. The development of the Use of Probing Questions for promoting student learning was explicit, as shown by the mentor teacher evaluation note: "*…The preservice teacher effectively used probing and open-ended questions that revealed students’ understanding.”*

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Findings for research question 2

Students' collaboration and teamwork competency was assessed across three indicators: 1) Good members and leadership, 2) Collaborative work process, and 3) Relationship building and conflict management. Each indicator was rated on a three-level scale according to OBEC (2021).

The level of collaboration and teamwork competency is shown in Table 2. Most students (20) demonstrated the Able level (Level 3) in the Collaborative Work Process during the redesigning stage, indicating strength in working collaboratively in later stages of the design process. In Good Members and Leadership, 14 students reached the Able level during prototyping. Conversely, most students (14) were still at the Beginner level (Level 1) in Relationship Building and Conflict Management during the problem identification stage. Overall, the Collaborative Work Process showed the most widespread competency, while Relationship Building appears to require further development, particularly in the early stages of teamwork.

Table 2: Collaboration and Teamwork Competency (N = 23).

Design process	**Collaboration and teamwork competency**								
	Good members and leadership			**Collaborative work process**			**Relationship building and conflict management**		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Identifying the need or defining the problem	-	-	-	-	-	-	14	9	0
Collecting information and researching	-	-	-	-	-	-	7	10	6
Generating ideas or alternatives	14	9	0	12	11	0	-	-	-
Choosing the best solution	0	15	8	1	8	14	-	-	-
Creating prototype	0	9	14	0	5	18	-	-	-
Testing prototype	0	8	15	0	4	19	-	-	-
Evaluating, reflecting or giving feedback	-	-	-	0	4	19	0	13	10
Redesigning	-	-	-	0	3	20	0	7	16

Details of each sub-competency are as follows:

Good members and leadership: By observing the students' group work behavior and presentations, the results indicated that students in groups 1, 2, and 3 discussed, exchanged opinions, and reached conclusions regarding the researcher's choice of materials. The students could identify whether to use cloth or plastic to create the directional airbags, as illustrated in Figure 4.

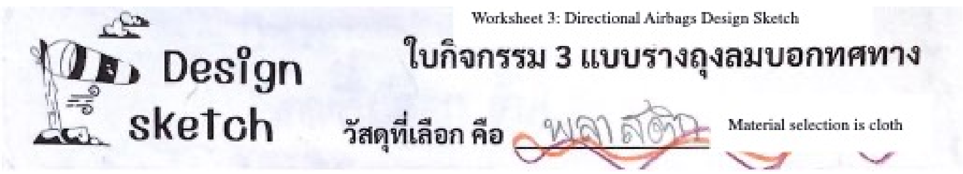


Figure 4: Activity sheet: Selection of materials used to create directional airbags for students in group 3.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

However, other groups of students each chose the materials they preferred, making it impossible for them to explain the reasons behind their choices. Instead, they presented the reasons given by other groups of friends regarding the selection of materials to create the directional airbags. Later, when choosing the appropriate method, students collaborated to plan and draft the directional airbags. The researcher divided the students into groups and assigned them tasks to manage within the group. Some groups allocated their responsibilities based on their abilities and listed their names beside each member, as shown in Figure 5.

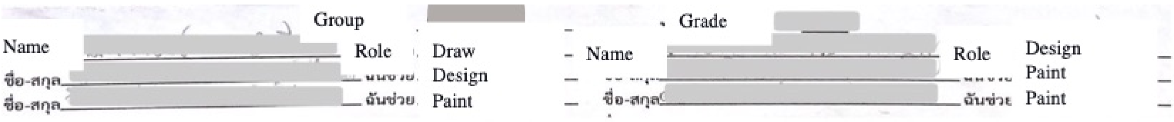


Figure 5: Division of duties in activities, draft of directional airbags

When students divide their roles, they identify their strengths and take pride in their contributions to the group. As a result, they understand different roles, assume responsibility, and assist one another in completing the work on time. Students remain accountable for their roles and cooperate effectively in building prototypes and testing the directional airbags. This is demonstrated in the following, as illustrated in Figure 6 and the dialogue.

Student 13: Does anyone want to color?
Student 19: We can color too.
Student 02: Let me be the one to cut the cloth.


Figure 6: The airbag prototype indicates the direction of students in groups 1, 2, 3, and 4.

In the testing activity, after each group of students successfully built the directional airbags, they took them to different locations to test their functionality. It was observed that the students adhered to the team's tasks and divided the work effectively.

Collaboration: Each group of students discusses and selects materials to create directional airbags. They present their reasons for choosing the materials, set goals, and maintain a group work process that aligns with those goals while taking responsibility for their assigned roles. They strive for success in their efforts and support each other as much as possible, both independently and collectively. They observe the activity of drafting the directional airbags before engaging, establishing specific design specifications, such as students' worksheets, as shown in Figure 7.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

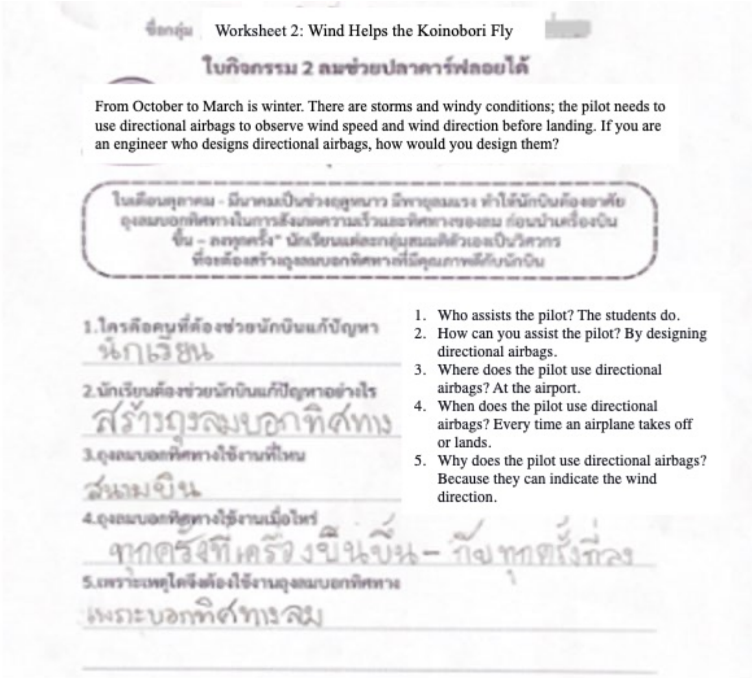


Figure 7: students' worksheets in group 1.

Later, while generating ideas and alternatives, students gathered information about the situation defined by the researcher and collectively proposed guidelines. Each group understood the team's goal and supported it by completing activities to achieve it, demonstrating their roles and responsibilities according to the steps and agreements established within the specified timeframe, as illustrated in Figure 8 and the dialogue.

Researcher: How did your team divide the tasks?

Student 03: Someone designed, drew, colored, and decorated.

Researcher: Did you complete the work within the specified time? If so, how?

Student 15: We finished on time as the teacher instructed. Researcher: How did your team complete the work within the specified time?

Student 10: We helped each other color and decorate to complete it quickly.

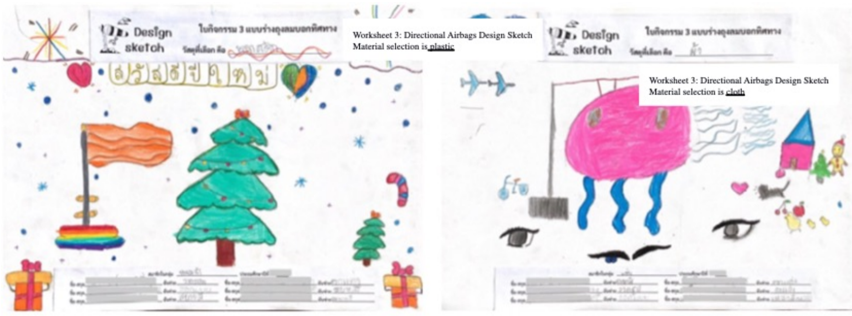


Figure 8: Airbag Direction Design for Groups 2 and 3 Students

In the testing activity, each group of students took their directional airbags to evaluate the functionality and record the test results at various locations specified by the researcher. They then jointly presented the findings of the directional airbags test. The discussion regarding the advantages and limitations of directional airbags, as well as suggestions for further development or improvement, is as follows:

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Researcher: After the test, what are the advantages and limitations of your directional airbags?

Group 2 students: It breaks easily.

Group 3 students: It is not attractive.

Group 4 students: It is too heavy and does not float well.

Researcher: Given the limitations, what adjustments would you make if there were an opportunity to improve the quality of the directional airbags?

Group 4 students: We will change the materials.

Group 2 students: We will make it thicker.

The conversation demonstrates that after the students reflected on their prototypes and recognized the issues that arose, as illustrated in Figure 9, they used the worksheet to assess the advantages and limitations of directional airbags. They collaborated on improvements throughout their work until they succeeded, as depicted in Figure 10. This illustrates the systematic process that led to the completion of their project by the established goals.

Figure 9: Worksheet to evaluate/reflect on the advantages and limitations of directional airbags

Figure 10: Directional airbags improvement worksheet

Relationship Building and Conflict Management: In identifying needs and problems, students collected data on the situation specified by the researcher and the conclusions drawn from the design. They recognized the feelings of others and responded to various situations according to the guidelines provided. Following the researcher's instructions, she demonstrated positive behaviors during conflicts, such as when student 03 positively remarked, "Should we use the voting method to choose

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

the group name?" During evaluations, reflections, or feedback sessions, each student group collaboratively reflected on their work after testing by identifying the advantages and limitations of their efforts. Students encouraged their peers to complete the activity sheets together. For instance, student 07 suggested using colored pencils during the reflection activity: "You can use colored pencils instead of magic colors, so you don't have to wait for the next color from your friends (Student 07)."

Additionally, student 22 praised their peers for motivating them in their reflection work, stating, "It's okay if you draw beautifully (Student 22). " They worked amicably, brainstorming together without arguing over resources. During improvement activities, they exhibited positive behaviors in conflicts by apologizing and forgiving one another.

After organizing all activities, it was observed that students displayed all the required components, particularly component 2, which involves the collaborative work process. Twenty students achieved level 3 competence in Component 3: Building Relationships and Conflict Management, and sixteen students demonstrated level 3 competence in Component 1: Building Relationships and Conflict Management.

CONCLUSION AND IMPLICATIONS

The results of this study suggest that STEM inquiry-based learning fosters collaboration and teamwork competencies in Grade 3 students by providing authentic contexts for skill application, peer interaction, and reflection. Throughout the iterative design process, students increasingly demonstrated competencies aligned with three key dimensions: effective participation and leadership, collaborative work processes, and relationship building, including conflict management, particularly during the prototype testing and redesign phases. The students' performance was assessed using a competency-based rubric (OBEC, 2021), which allowed for the observation of progressive abilities enactment in authentic learning contexts. These findings align with previous research (Nilubon, 2023; Khamta et al., 2023), indicating that STEM inquiry-based learning enhances students' social and collaborative engagement through real-world problem-solving and shared responsibilities. Furthermore, the observed development in students' ability to co-create, reflect, and redesign artifacts affirms the importance of integrating inquiry with design thinking in primary STEM education.

The findings are further supported by King and English (2016), who emphasized that integrating STEM concepts through iterative design provides primary students with opportunities to apply scientific and mathematical thinking in meaningful, hands-on contexts. Their research highlights the significance of the design sketch stage, collaborative group work, and opportunities for reflection and redesign in developing STEM understanding and teamwork. This study also showed these aspects as students progressed from beginner-level interaction to more proficient collaboration, particularly during the redesign phase.

Implications for classroom practice include embedding structured STEM inquiry-based learning that integrates the design process and inquiry, which scaffolds students' reasoning and promotes deeper collaboration. Teachers are encouraged to emphasize flexibility in group roles, clear communication, and guided reflection throughout the learning process. Additionally, educators might consider extending the time allocated for redesign and discussion stages to maximize the potential for integrating more complex STEM issues. Future research could explore how these approaches affect students' long-term retention of collaborative skills and STEM understanding, as well as how differentiated scaffolding might further enhance group dynamics in mixed-ability classrooms.

Implications for classroom practice include intentionally structuring STEM inquiry-based learning with a focus on group dynamics, role flexibility, and reflective dialogue. Teachers should emphasize guided questioning, equitable participation, and opportunities for peer negotiation and decision-making. Future research may investigate how sustained engagement with STEM inquiry activities supports the long-term development of collaboration competencies, particularly among learners from diverse backgrounds and abilities.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

In this study, we conceptualize competency not as prior knowledge or static achievement, but as an ability cultivated and enacted through guided practice and performance-based tasks. As such, a pre-post comparison, suitable for measuring cognitive achievement, was not applied here, since competencies emerge primarily through sustained engagement rather than prior instruction. To address this concern, we have revised the Conclusion section to reflect the theoretical grounding of competency-based education. We clarified that students' increasing demonstration of collaboration and teamwork was assessed using a national competency rubric (OBEC, 2021).

Limitations of this study included its conduct within a single Grade 3 classroom during the first author's teaching practicum, which may limit the generalizability of the findings to broader contexts. Additionally, while the thematic analysis was carefully conducted and validated through peer debriefing, the interpretation of qualitative data was still largely dependent on the researcher's reflective perspective. Furthermore, collaboration and teamwork were assessed using performance-based rubrics. Although these rubrics align with national competency standards, they may not fully capture the nuanced development of interpersonal dynamics or long-term behavioral change. Future research could investigate the implementation of STEM inquiry-based learning across multiple classrooms or schools to assess its effectiveness in diverse educational contexts. Longitudinal studies would aid in examining how sustained engagement with STEM inquiry activities fosters the development and retention of collaboration and teamwork competencies over time.

REFERENCES

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.

Nilubon, C. (2023). *Developing teamwork and communication competencies of Grade 1 students through STEM learning using inquiry-based learning* (Master's thesis, Kasetsart University).

Samahito, C. (2014). Organizing learning experiences based on STEM education in early childhood education. *Journal of Education Review,* 30(2), 102–111.

Khamta, N., Phanphruaksa, K., & Latuang, T. (2023). The effects of inquiry-based learning (5E model) integrated with STEM education on Grade 6 students' learning achievement and problem-solving skills (Master's thesis, Burapha University, Chonburi).

King, D. and English, L. (2016). Engineering design in the primary school: applying STEM concepts to build an optical instrument. International Journal of Science and Education, 38(18), 2762-2794.

Pimthong, P. (2023). *STEM education instruction* (2nd ed.). Bangkok: Sunthorn Film Co., Ltd.

Saifa, Y. (2014). Concepts of STEM learning management. Unpublished instructional material, Department of Elementary Education, Faculty of Education, Chulalongkorn University.

Institute for the Promotion of Teaching Science and Technology. (2014). *STEM education: Science, technology, engineering and mathematics education* (1st ed.). Bangkok: Author.

Office of the Basic Education Commission, Ministry of Education. (2021). *Teamwork competence.* Retrieved January 12, 2025, from https://cbethailand.com/download/6640/

Office of the Education Council. (2019). *Core competency framework for students in basic education and lower primary levels (Grades 1–3)*. Bangkok: Office of the Education Council.

Office of the Education Council. (2021). *Guidelines for developing students' competencies in basic education*. Bangkok: Ministry of Education.

.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

International Journal of Science Education and Teaching
Vol. 4, No. 2, pp. 77-92, May. – Aug. 2025
http://doi.org/10.14456/ijset.2025.06

Enhancing Scientific Argumentation Skills in Chemistry on the Topic of Chemical Bonding through Argument-Driven Inquiry of Grade-10 Students

Potjana Ponil[1*], Panwilai Dokmai[2]
[1]*Master Science Education Program, Rajabhat Maha Sarakham University, Thailand*
[2]*Master Science Education Program, Rajabhat Maha Sarakham University, Thailand*
*Email: 668010300105@rmu.ac.th

Received: 25 Mar. 2025 Revised: 20 May. 2025 Accepted: 22 May. 2025

Abstract. This research aimed to develop the scientific argumentation skills of Grade-10 students on the topic of chemical bonding through argument-driven inquiry. The action research study was conducted with the target group of 10 grade-10 students from Mueang Mahawichanukool School, Maha Sarakham Province. The participants were enrolled in the first semester of the 2024 academic year. These research tools were: 1) Argument-driven inquiry lesson plans on the topic of chemical bonding, consisting of 11 plans with duration time of 22 hours, 2) Scientific argumentation skills test included three questions from three scenarios for measuring student's argumentation skills after each operational cycle. The test has IOC validity ranging from 0.89 to 1.00 and reliability coefficient of 0.8 and 3) Observation form for scientific argumentation behavior observation. Quantitative data were analyzed by mean ($\bar{x}$), standard deviation (S.D.), and percentage (%). Qualitative data was analyzed through content analysis. The research results found that the first operational cycle, two students (20%) had scientific argumentation skills at a good level, five students (50%) at a moderate level, and three students (30%) at a low level. In the second operational cycle, two students (20%) had scientific argumentation skills at a very good level, two students (20%) at a good level, four students (40%) at a moderate level, one student (10%) at a low level, and one student (10%) at a very low level. In the third operational cycle, three students (30%) had scientific argumentation skills at a very good level, one student (10%) at a good level, and six students (60%) at a moderate level. Students exhibited an increased level of scientific argumentation skills, with the observed progression across all components of argumentation.

Keywords: Argument-Driven Inquiry, Action Research, Scientific Argumentation Skills, Chemical Bonding

INTRODUCTION

In the 21st century, rapid advancements in science and technology have significantly influenced society, making education essential for developing high-quality individuals with the skills and competencies needed for this era. The Basic Education Development Plan (2023–2027) identifies critical 21st century skills, focusing on the 3Rs and the 8Cs (Office of the Basic Education Commission, 2022). These objectives align with the Basic Education Core Curriculum 2008, focus on developing students' competencies in communication, information literacy, analytical thinking, decision making, and problem solving, with a strong emphasis on the consideration of social impacts. Preparing learners with these essential skills is crucial in today's educational context. (Ministry of Education, 2008). In the digital age, where information disseminates rapidly, propaganda and persuasive advertisements have become an integral part of daily life. To make

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

accurate and well-informed decisions, individuals must engage in logical reasoning supported by credible evidence. This process of thoughtful decision making, grounded in scientific reasoning and evidence, necessitates the use of scientific argumentation as a key tool for in the evaluation process (Jantarakantee, 2016).

Scientific argumentation refers to the process of validating claims in the field of science using evidence and reasoning. It involves constructing and presenting arguments based on scientific evidence to support or refute claims or hypotheses (Erduran, 2019). This process encompasses claims, supporting reasoning, the use of evidence, counter arguments, and rebuttals grounded in evidence (Lin & Mintzes, 2010). Scientific argumentation is a critical process for students as it helps them develop critical thinking skills, problem solving abilities, and teamwork capabilities. It enables students to gain a deeper understanding of scientific concepts and fosters the mindset of a scientist (Özelma & Seyhan, 2022). Moreover, scientific argumentation enhances social interactions and interpersonal communication skills. It provides students with opportunities not only to share their perspectives but also to understand diverse viewpoints through the argumentation process (Celep, 2015). The argumentation skills not only help students become scientifically literate but also enhance higher order thinking skills, scientific process skills, communication skills, and the ability to evaluate the credibility of information, which are the primary goals of science education (Jantarakantee, 2016). Furthermore, scientific argumentation serves as a foundational skill that facilitates the development of other competencies, including analytical thinking, distinguishing between facts and opinions, fostering participatory learning, improving communication skills, cultivating informed citizenship, and enhancing educational quality. This skill is indispensable for 21st century work environments, equipping students for success in life as informed citizens who can communicate effectively and contribute constructively to society (Pharanat & Nuarngchalerm, 2018).

According to a study by the Organization for Economic Co-operation and Development (OECD), data on the ability to combat fake news and misinformation among 15-year-olds across 77 countries revealed that Thai students ranked 76th out of 77 countries. This indicates that Thai students have a significantly low capacity for filtering fake news (OECD, 2021). The primary cause of this issue is the lack of critical thinking skills, which are essential for distinguishing accurate information from misinformation. Critical thinking acts as a compass, guiding individuals to focus on facts, credible opinions, and disregard unsupported or deliberately distorted information. This aligns with findings from Mueang Mahawichanukool School's self-assessment report, which identified that some students lack analytical thinking, systematic problem-solving, and critical thinking skills. Similarly, during observation and practicum, the researcher found that most students lacked the ability to construct arguments, provide logical reasoning, and present credible evidence of key components of critical thinking. These skills are fundamental for analyzing and evaluating problems using logic, reasoning, and systematic decision-making, which enables the creation of new, reliable knowledge (Mueang Mahawichanukool School, 2022). The assessment of the scientific argumentation skills of ten students revealed that only one student demonstrated a good level of scientific argumentation; four students were at a moderate level, another four were at a low level, and one student was at a very low level. This demonstrates a general lack of argumentation skills among students. Furthermore, an analysis of the components of argumentation indicated deficiencies in students' ability to provide reasoning, present evidence, and effectively counterargue. These shortcomings stem from an overall lack of analytical thinking skills. The issues outlined are critical components of critical thinking skills, which can be cultivated through the practice of argumentation (Rusmini, 2021). Enhancing these skills through targeted instruction and practice is essential for empowering students to think critically and respond effectively to challenges in the modern information age.

Approaches to designing activities that enhance students' scientific argumentation skills, enabling them to better understand, connect content, and apply knowledge in explaining or summarizing concepts using credible and accurate scientific evidence and reasoning, including various models. These models include open-ended learning (Maneetup & Harnsoongnoen, 2023), jigsaw learning, informal cooperative learning, and argument-driven inquiry (Amelia, Asrial, & Effendi-Hasibuan, 2020). Among these approaches, the researcher selected argument-driven inquiry to develop scientific argumentation skills. Argument-driven inquiry (ADI) is a science

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

teaching method emphasizing the creation of arguments, examination of evidence, and data analysis through inquiry and evidence gathering to construct arguments and summarize information (Janhom & Jantrasee, 2019). This method is more suitable than open-ended learning, which lacks specific argumentation steps, does not fully engage students in argumentation practice, and does not require written argument evaluation reports. It is also more effective than jigsaw learning and informal cooperative learning. This conclusion is supported by the study of Amelia, Asrial, & Effendi-Hasibuan (2020), which compared the argumentation skills fostered by three learning approaches: jigsaw learning, informal cooperative learning, and argument-driven inquiry. The results showed that argument-driven inquiry was the most effective in promoting argumentation skills. Similarly, research by Amelia, Suciati, & Maridi (2018) compared students' argumentation skills argument-driven inquiry versus traditional teaching methods. The findings indicated that argument-driven inquiry significantly enhanced students' argumentation skills compared to conventional classroom instruction. As discussed above, general instructional methods that do not include explicit steps for argumentation often result in less effective development of students' argumentation skills. In contrast, argument-driven inquiry incorporates specific steps designed to foster argumentation, making it more effective than traditional teaching methods. This approach emphasizes the development of scientific argumentation skills through the construction of arguments, examination of evidence, and data analysis. It involves inquiry and evidence-based exploration to construct arguments and summarize information (Janhom & Jantrasee, 2019).

In chemistry education, the subject matter is highly specialized and often operates at the microscopic level, involving real but invisible phenomena. The content is complex and interdisciplinary, making it difficult for students to grasp. Traditional lecture-based teaching often limits students' opportunities for critical thinking and independent knowledge construction, which may hinder their ability to understand and integrate scientific concepts (Kamart & Wara-asawapati Srisa-ard, 2022). One such topic is chemical bonding fundamental concepts essential for understanding the structure of matter, chemical reactions, and properties of substances. Due to its abstract nature, many students struggle to comprehend bonding concepts effectively. Scientific argumentation helps deepen students' understanding by encouraging active engagement through making claims, using evidence, and logical reasoning. It fosters inquiry, clarifies misconceptions, and promotes explanation in students' own words, especially useful for abstract topics like chemical bonding. Argumentation also supports peer interaction, enabling students to evaluate ideas and build clearer conceptual understanding together. To address this challenge, the researcher adopted an argument-driven inquiry approach to improve students' scientific argumentation skills. These skills are critical for logical reasoning, evidence-based explanation, and the evaluation of multiple perspectives. They also support students in making informed decisions, distinguishing facts from opinions, and engaging in analytical, evidence-driven discussions. This approach is consistent with the findings of Walker & Sampson (2013), who demonstrated that argument-driven inquiry promotes deeper conceptual understanding and critical thinking by engaging students in scientific practices such as designing experiments, analyzing data, and constructing arguments based on evidence. The argument-driven inquiry model also aligns with constructivist learning theory, which emphasizes that students actively build knowledge through inquiry, discussion, and social interaction, making it particularly effective in abstract and complex subjects like chemistry.

RESEARCH OBJECTIVES

Enhancing the scientific argumentation skills of grade 10 students on the topic of chemical bonding through argument-driven inquiry.

METHODOLOGY

This study is action research aimed at developing students' scientific argumentation skills through argument-driven inquiry. The research process follows the four-step model proposed by Kemmis & McTaggart (1988), which includes: 1) Planning, 2) Action, 3) Observation, and 4) Reflection. The study consists of three operational cycles.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Target Group

The target group of this research was 10 tenth-grade students enrolled in a chemistry course during the first semester of the 2024 academic year at Mueang Mahawichanukool School, a small-sized secondary school in which the entire Grade 10 cohort comprises only ten students. Some students lacked analytical thinking, systematic problem-solving, and critical thinking skills and based on observation and practicum, the researcher found that most students still demonstrated limited abilities in constructing and engaging in scientific argumentation. Therefore, these ten students were selected as the target group for this study.

Research Tools

The research tools used in this study can be categorized into three types.

1. Learning management: Argument-driven inquiry plans on the topic of chemical bonding, consisting of 11 lesson plans over a total of 22 hours. The learning process consists of eight steps: 1) identifying the task, 2) gathering information, 3) constructing arguments, 4) argumentation activities, 5) writing an investigation report, 6) peer evaluation, 7) revising the report, and 8) reflective discussion. The learning management plans were evaluated for quality using a Likert scale, a 5-point rating scale. The results indicated that the plans were deemed highly appropriate, with mean scores ($\bar{x}$) ranging from 4.88 to 4.91.

2. Scientific argumentation skills test: This test was subjective and included three questions from three scenarios for measuring student's argumentation skills after each operational cycle. In the first operational cycle, the assessment was based on scenarios related to the ionic bond. The second operational cycle involved scenarios of the covalent bond, while the third operational cycle focused on scenarios related to the applications of ionic compounds, covalent compounds, and metals. The test qualities showed difficulty ranging from 0.36 to 0.50, a discrimination index between 0.61 and 0.93, and the reliability of 0.86. The rubric for assessing scientific argumentation skills demonstrated an inter-rater reliability of 0.93.

Aunt Daeng was cooking curry in a new pot. After finishing the meal, she found burnt stains at the bottom of the pot. She wanted to clean the burnt stains, but at home, she only had salt and baking soda, no dishwashing liquid. The two substances have the following properties:

Substance	Properties
Salt (NaCl)	Neutral pH, white crystalline powder, odorless, dissolves well in water, increases water conductivity, produces Na^+ and Cl^- ions in water.
Baking Soda ($NaHCO_3$)	Mildly alkaline, a fine white crystalline powder, water-soluble, odorless, and when dissociated and reacted, it helps reduce acidity.

Aunt Daeng watched a video demonstrating how to use substances to clean a pot with heavy black stains, using three different formulas:

1. Mix 1 tablespoon of salt with enough water to make a thick paste. Apply to the stained area of the pot, leave for 45 minutes, then gently scrub with a sponge.
2. Mix 2 cups of baking soda with 1/2 cup of water. Apply the mixture to the black stains, leave for about 30 minutes, then gently scrub off the stains with a sponge.
3. Mix 1 cup of baking soda with 1/2 cup of salt. Apply the mixture to the black stains, leave for about 40 minutes, then scrub off the stains with a sponge.

Based on the information above, if you were Aunt Daeng, which method would you choose to clean the burnt stains on the pot?

Noon is a first-year university student who has recently moved into a dormitory and wants to cook her own dinner to save money. She is currently deciding between buying a pot or pan made of aluminum and one made of steel. To make an informed decision, she is considering the properties of both materials.

Aluminum conducts heat well and distribute it evenly, making it suitable for cooking methods that require consistent heat, such as stir-frying, frying, and boiling. In addition, aluminum cookware is lightweight, making it easy to lift and move.

On the other hand, pots or pans made of steel retain heat effectively, allowing food to cook thoroughly and stay warm for longer periods. Steel is also more durable than aluminum, meaning it can last longer and withstand more use. Moreover, steel is safer for health, as it does not react with food, reducing the risk of metal contamination.

The Little Girl and the Oil Stain on Her Shirt

One evening at a small house, little Mind was playing with oil paints at the garden table. She accidentally spilled some paint onto her white T-shirt. Shocked, she looked at the oil stain on her shirt, knowing her mother would surely scold her.
"Mom, I spilled oil paint on my shirt," Mind said quietly.
Her mother came over to examine the stain. "Oh, Mind, I told you not to play with oil paint alone," she said firmly.
"I know, I'm sorry," Mind replied, hanging her head.
"Give me the shirt. Let me see if I can wash it out," her mother said.
She took the t-shirt to the sink, turned on the water, and tried to scrub the stain by hand. However, the oil paint remained stubbornly stuck to the fabric.
"Why won't it come out, Mom?" Mind asked.
"Because oil paint is made up of non-polar molecules," her mother explained. "Water is a polar molecule, and polar molecules attract other polar molecules, but they don't attract non-polar ones."
"So what should I do?" Mind asked.
"I have a special dishwashing liquid designed to remove oil stains," her mother replied. "Dishwashing liquids contain chemicals with non-polar molecules. These can attract the oil paint molecules and help lift them from the fabric."
Her mother applied the dishwashing liquid to the stain and gently scrubbed it with a sponge. Slowly, the stain faded and came off the shirt.
"Yay! The paint stain is gone!" Mind cheered.
From this experience, Mind learned that chemical substances with appropriate polarity are key to cleaning different types of stains.

Figure 1: Sample scenarios in each cycle of the operation.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

3. Observation form for scientific argumentation behavior observation: This form was used to observe and assess students' levels of scientific argumentation skills. It also served as a basis for developing and improving learning activities aimed at enhancing students' scientific argumentation abilities.

Data Collection

In this study, the researcher collected data during the first semester of the 2024 academic year, covering 11 lesson plans with a total of 22 hours. The data collection was conducted over three operational cycles, with the following collection procedures:

1. Planning: The researcher surveyed the current issues and learning environment of tenth-grade students at Mueang Mahawichanukool School to identify problems and explore suitable learning strategies. The assessment revealed that students lacked key scientific argumentation skills such as warrants, evidence, supportive arguments, and counter arguments due to limited analytical thinking. To address this, the researcher adopted an argument-driven inquiry approach and reviewed the curriculum to design 11 lesson plans on chemical bonding for the first semester of the 2024 academic year. The plans were reviewed by the advisor and subject-matter experts for alignment and appropriateness, revised based on their feedback, and prepared for implementation in the next research phase.

2. Action: The revised lesson plans, which were updated based on feedback from the advisor and experts, were implemented with the target group, starting from the first operational cycle through to the third operational cycle. The learning management plan for each operational cycle is presented in Table 1.

Table 1: The learning management plan for each operational cycle.

Cycles	Learning management	Time (hr.)
1	Lesson plan 12: Lewis dot symbols and the formation of ionic bonds	2
	Lesson plan 13: Chemical formulas and nomenclature of ionic compounds	2
	Lesson plan 14: Energy and the formation of ionic compounds	2
	Lesson plan 15: Properties of ionic compounds and ionic equations and net ionic equations	2
2	Lesson plan 16: Formation and types of covalent bonds	2
	Lesson plan 17: Writing formulas and naming covalent compounds	2
	Lesson plan 18: Bond length and bond energy of covalent compounds	2
	Lesson plan 19: Molecular shape and polarity of covalent molecules	2
3	Lesson plan 20: Intermolecular forces and properties of covalent compounds	2
	Lesson plan 21: Covalent network structures	2
	Lesson plan 22: Metallic bonds and the applications of ionic compounds, covalent compounds, and metals	2
Total		**22**

The learning process was designed based on an argument-driven inquiry by Sampson & Gleim (2009) which consists of the following eight steps:

1) Identifying the task: This step introduces the topic of study, connects students' prior knowledge with new concepts, and stimulates their interest. A problem and the subject of investigation are clearly defined.

2) Gathering information: Students work in groups to design experiments or conduct inquiries, gather information, and analyze the data obtained from their experiments and investigations.

3) Constructing arguments: Students will synthesize the information obtained from their inquiry, engage in idea exchange, and collaborate to solve problems within their group. They will provide justifications by explaining how their claims are supported by the evidence and evaluate whether the reasoning is accurate and consistent with the data.

4) Argumentation activities: Students present, support, and critique their explanations and opinions through classroom presentations and discussions. These discussions allow students to articulate and justify the arguments they have constructed, as well as to challenge the opinions of others that are considered inconsistent with scientific concepts.

5) Writing an investigation report: This step involves students writing about the outcomes of their investigation in the form of a report or a written reflection. It enables them to

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

express their own ideas clearly and concisely. The report should include key components such as claims, evidence, and reasoning.

6) Peer evaluation: Students evaluate their peers' reports and decide whether the report is acceptable or needs revision based on the criteria provided in the evaluation form, without identifying the evaluator as part of the knowledge review process.

7) Revising the report: In this step, students revise or rewrite their reports based on the feedback from the evaluator and then submit the revised report to the teacher for further review.

8) Reflective discussion: Summarize the results of the investigation and the concepts derived from the inquiry or experiment, ensuring they align with established theories and laws.

3. Observation: Students were observed and assessed during the argument-driven inquiry. Data was collected on the development of their scientific argumentation skills through the scientific argumentation skills test, and an observation form for scientific argumentation behavior observation. This data was used to reflect on the outcomes of the learning process.

4. Reflection: The researcher reflected on the learning outcomes of the argument-driven inquiry by using the observation form for scientific argumentation behavior observation post-lesson reflection and the scientific argumentation skills test at the end of each operational cycle. The results were analyzed to identify issues encountered in each scientific argumentation behavior during the learning process. These identified issues were then used to improve and adjust the learning management to address these problems next to the operational cycle.

Data Analysis

1. Quantitative Data Analysis: Students' scientific argumentation skills were assessed using the scoring rubric outline in Table 2, and the collected data were transformed into scores ranging from 0 to 10, which were then categorized into levels: very good (8-10 points), good (6-7 points), moderate (4-5 points), low (2-3 points), and very low (0-1 points) and then the scores of each argumentation component will be analyzed using elementary statistics including mean, standard deviation, and percentage.

2. Qualitative Data Analysis: The scientific argumentation behavior was analyzed using content analysis methods. The data from observations were analyzed and interpreted based on the components of scientific argumentation, which include claims, warrant, evidence, counter arguments, and supportive argument. And then the data were summarized for reporting the research findings, divided into the problems encountered and the solutions implemented in each operational cycle.

Table 2: Rubric for assessing scientific argumentation skills.

Questions	Components of an argument	Scoring criteria 0	1	2
1	Claim	No claim	The claim is complete but incorrect	The claim is both complete and correct.
	Warrant	No reasoning is provided, or the reasoning provided does not connect the claim to the evidence.	The reasoning provided connects the claim to the evidence, but it is insufficient.	The reasoning provided connects the claim to the evidence and is supported by scientific methods.
2	Evidence	There is no evidence to support the claim, or the evidence provided does not support the claim.	There is some appropriate but insufficient evidence to support the claim.	There is sufficient and appropriate evidence to support the claim.
3	Counter Argument	No argument is presented.	A counter argument is presen but the explanation is inappropriate.	A counter argument is presented appropriately, with a suitable explanation.
	Supportive Argument	No counter argument is provided.	A counter argument is provided, but the reasoning and evidence are insufficient.	A counter argument is provided with sufficient reasoning and evidence.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

RESULTS AND DISCUSSION

The survey of the scientific argumentation skills of 10 tenth-grade students before the instructional through argument-driven Inquiry. The results showed that only one student at a good level of scientific argumentation skills, four students at a moderate level, four students at a low level, and one student at a very low level, as shown in Table 3.

Table 3: Results of the scientific argumentation skills assessment before entering the first operational cycle.

ID	Scientific argumentation skills: Claims (Score 2)	Evidence (Score 2)	Warrant (Score 2)	Counter Arguments (Score 2)	Supportive Argument (Score 2)	Total (Score 10)	Level
1	1	1	1	0	0	3	Low
2	2	0	0	0	0	2	Low
3	2	1	0	1	1	5	Moderate
4	2	1	0	0	2	5	Moderate
5	2	1	1	1	0	5	Moderate
6	2	1	1	0	1	5	Moderate
7	2	0	1	0	0	3	Low
8	2	1	1	2	1	7	Good
9	2	0	1	0	0	3	Low
10	1	0	0	0	0	1	Very low

From Table 3, students exhibited difficulties in nearly all aspects of scientific argumentation. They struggled with warrant, evidence, supportive argument, and counter-argumentation. These challenges were attributed to a lack of analytical thinking skills. Therefore, the researcher selected all ten students as the target group to develop their scientific argumentation skills through argument-driven inquiry**.**

The results of developing scientific argumentation skills after implementing argument-driven inquiry in the first operational cycle. At the end of the learning process of the first operational cycle, the researcher employed a scientific argumentation skills test encompassing all five components of argumentation: 1) claims, 2) evidence, 3) warrant, 4) counter arguments, and 5) supportive argument. The results were analyzed and evaluated to identify issues for reflection. The assessment results of scientific argumentation skill in the first operational cycle were presented in Table 4.

Table 4: The assessment results of scientific argumentation skills after the learning process in the first operational cycle.

ID	Scientific argumentation skills: Claims (Score 2)	Evidence (Score 2)	Warrant (Score 2)	Counter Arguments (Score 2)	Supportive Argument (Score 2)	Total (Score 10)	Level
1	1	1	1	0	1	4	Moderate
2	2	0	0	0	0	2	Low
3	2	1	0	1	1	5	Moderate
4	2	1	0	0	2	5	Moderate
5	2	2	1	2	0	7	Good
6	2	1	1	0	1	5	Moderate
7	2	0	1	0	1	4	Moderate
8	2	1	1	2	1	7	Good
9	2	0	1	0	0	3	Low
10	2	0	0	0	0	2	Low
$\bar{x}$	1.9	0.7	0.6	0.5	0.7	4.4	
S.D.	0.32	0.68	0.52	0.85	0.66	1.8	

From Table 4, the students' scientific argumentation skills were assessed as follows: two students (20%) at a good level, five students (50%) at a moderate level, and three students (30%) at a low level. When considering the average scores for each component of argumentation, the students scored the highest in the claim ($\bar{x}$ = 1.9), followed by evidence ($\bar{x}$ = 0.7), supportive

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

argument ($\bar{x}$ = 0.7), warrant ($\bar{x}$ = 0.6), and counter arguments ($\bar{x}$ = 0.5), respectively. The problems encountered in the first operational cycle included students' lack of confidence in using evidence, unclear connections between warrants and evidence, and insufficient scientific writing skill.

An example of a student's response from the scientific argumentation skills tests the first operational cycle.

1. Which formula should Aunt Daeng choose to remove the black stains in the pot, and why? *(Claim and Warrant: 4 score)*

Student A: Formula three, because baking soda helps remove the black stains, and salt does as well.

Student B: Formula two contains the highest amount of baking soda, which has properties that effectively break down burnt stains from pots, softening the stains and making them easier to remove.

2. What information supports Aunt Daeng's decision to use that formula to clean the burnt stains in the pot? *(Evidence: 2 score)*

Student A: Information from the table.

Student B: The information in the table indicates that baking soda is soluble in water and effective in cleaning, particularly for removing food stains with acid residues allowing time for the chemical reaction to take place.

3. If a friend gives an answer different from yours in Question 1, what do you think their reasoning might be, and how would you persuade them to agree with your viewpoint? *(Counterargument and supportive argument: 4 score)*

Student A: Explain in a way that both parties understand and persuade the friend to consider the perspective.

Student B: We should first listen to our friend's reasoning, and if they have a different opinion, we can respond by explaining that both salt and baking soda are good at absorbing moisture and can also help reduce acidity.

Based on the problems encountered in the first operational cycle, In the second operational cycle, the researcher used questions to stimulate students to make connections between evidence and warrant for claims. The researcher emphasized that there was no right or wrong when it came to finding supporting evidence for one's claims. The students were trained to write scientific explanations by using prompting questions that encouraged them to explain their arguments and reasoning, while also pointing out how evidence and reasoning were interconnected. According to the study by Suwannatrai & Sangpradit (2023), teachers incorporated questions related to scientific problems into their lesson plans. This approach helped establish connections between prior knowledge and new concepts while also encouraging students to think critically and present their own claims, along with the warrant used to support those claims. The assessment results of scientific argumentation skill in the second operational cycle were presented in Table 5.

Table 5: The assessment results of scientific argumentation skills after the learning process in the second operational cycle.

ID	Scientific argumentation skills					Total (Score 10)	Level
	Claims (Score 2)	Evidence (Score 2)	Warrant (Score 2)	Counter Arguments (Score 2)	Supportive Argument (Score 2)		
1	2	0	1	0	0	3	Low
2	0	1	0	0	0	1	Very low
3	2	0	1	0	1	4	Moderate
4	2	1	1	2	1	7	Good
5	2	1	2	2	1	8	Very good
6	2	1	0	1	1	5	Moderate
7	2	1	1	0	0	4	Moderate
8	2	2	1	2	2	9	Very good
9	2	0	2	0	0	4	Moderate
10	2	1	2	1	0	6	Good
$\bar{x}$	1.8	0.8	1.1	0.8	0.6	5.1	
S.D.	0.63	0.63	0.74	0.92	0.70	2.42	

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

From Table 5, the students' scientific argumentation skills were assessed as follows: two students (20%) at a very good level, two students (20%) at a good level, and four students (40%) at a moderate level, one student (10%) is at a low level and one student (10%) is at a very low level. When considering the average scores for each component of argumentation, the students scored the highest in the claims ($\bar{x}$ = 1.8), followed by use of warrant ($\bar{x}$ = 1.1) evidence ($\bar{x}$ = 0.8) counter arguments ($\bar{x}$ = 0.8) and supportive argument ($\bar{x}$ = 0.6) respectively. The problems encountered in the second operational cycle include some students still struggling to articulate their claims clearly and accurately. While they were able to gather additional supporting evidence, it remained insufficient and lacked clarity. Furthermore, some students faced difficulties in counter arguments and supportive arguments.

An example of a student's response from the scientific argumentation skills tests the second operational cycle.

1. Do you agree or disagree with the statement that polar substances can clean all types of stains? Why or why not? *(Claim and Warrant: 4 score)*

Student A: I disagree, because some types of stains, such as oil or paint stains, are non-polar substances, which cannot be dissolved or removed with water, a polar substance.

Student B: I disagree that polar substances can clean all types of stains, because polar substances can only clean stains that are made of similar polar substances, such as water. However, for stains that are non-polar, like oil or paint stains, polar substances cannot attract or clean them effectively.

2. What information supports your opinion in question 1? *(Evidence: 2 score)*

Student A: Mind's mother tried washing the stain with water, but it did not come off. She had to use dishwashing liquid, which contains non-polar substances that were able to remove the stain.

Student B: When Mom tried to wash the shirt with plain water, which is a polar substance, it could not remove the oil paint stain.

3. If a friend gives an answer different from yours in Question 1, what do you think their reasoning might be, and how would you persuade them to agree with your viewpoint? *(Counterargument and supportive argument: 4 score)*

Student A: If a friend agrees, you should consider their reasoning first. Then, explain the correct principles in a credible manner to persuade them.

Student B: They might think that plain water or general cleaning products, which are often polar substances, can clean all types of stains. You can persuade them by explaining that non-polar stains require non-polar substances to be effectively removed.

In the third operational cycle, the researcher implemented strategies to address the problems identified in the second operational cycle by reviewed the claims and data from other groups, asking students to take notes, and inquired whether they wanted to change their answers. This was done to help students recognize arguments different from their own. Additionally, learning media, such as survey boards, were used to help students visualize and use evidence to support their claims and supportive arguments. The consists of a study by Sampson & Gleim (2009), which prepares a list of necessary materials for inquiry-based learning, such as samples, models, slides, experimental equipment, and facilitate data collection to support claims. Regarding counter arguments and supportive arguments, providing alternative claims requires reviewing students' counter arguments, encouraging analytical thinking to develop counter arguments, guiding discussions to remain focused, and summarizing key points. The assessment results of scientific argumentation skill in the third operational cycle were presented in Table 6.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Table 6: The assessment results of scientific argumentation skills after the learning process in the third operational cycle.

ID	Scientific argumentation skills: Claims (Score 2)	Evidence (Score 2)	Warrant (Score 2)	Counter Arguments (Score 2)	Supportive Argument (Score 2)	Total (Score 10)	Level
1	2	1	1	0	1	5	Moderate
2	1	1	1	0	1	4	Moderate
3	2	1	1	2	2	8	Very good
4	2	1	1	0	1	5	Moderate
5	2	1	2	2	1	8	Very good
6	2	1	1	0	1	5	Moderate
7	2	1	2	0	0	5	Moderate
8	2	2	2	2	2	10	Very good
9	2	1	1	0	1	5	Moderate
10	2	0	2	2	0	6	Good
$\bar{x}$	1.9	1	1.4	0.8	1	6.1	
S.D.	0.32	0.47	1.03	0.6	0.67	1.91	

From Table 6, the students' scientific argumentation skills were assessed as follows: three students (30%) at a very good level, one student (10%) at a good level and six students (60%) at a moderate level. When considering the average scores for each component of argumentation, the students scored the highest in the claims ($\bar{x}$ = 1.9), followed by use of warrant ($\bar{x}$ = 1.4) evidence ($\bar{x}$ = 1.0) supportive argument ($\bar{x}$ = 1.0) and counter arguments ($\bar{x}$ = 0.8) respectively. The problems encountered after completing the third operational cycle reveal that students have improved their argumentation skills, but inconsistently. They lack skills in data analysis which results in arguments that are not comprehensive and lack depth. Some students forget to consider other counter arguments and focus solely on supportive arguments.

An example of a student's response from the scientific argumentation skills tests the third operational cycle.

1. What type of material should Noon choose for her pan, and why? *(Claim and Warrant: 4 score)*

Student A: Noon should choose to use a pan made of aluminum because aluminum conducts heat well, allowing food to cook quickly and evenly.

Student B: Noon should choose a pan made of iron because iron retains heat for a long time, making it suitable for slow-cooking or baking dishes that require extended cooking time. It is also highly durable.

2. What information supports Noon's choice of that material? *(Evidence: 2 score)*

Student A: Aluminum distributes heat evenly and is lightweight, making it convenient for everyday use, especially for students who may have limited time.

Student B: Iron is strong and durable, does not leach metal contaminants into food, and has a long lifespan, making it more cost-effective than frequently replacing aluminum cookware.

3. If a friend gives an answer different from yours in Question 1, what do you think their reasoning might be, and how would you persuade them to agree with your viewpoint? *(Counterargument and supportive argument: 4 score)*

Student A: If my friend chooses an iron pan, they might think that iron is strong and safer for health. However, I would explain that in daily life, Noon may need to be cooked quickly and frequently, so the fast heat distribution of aluminum might be more suitable. With careful use, aluminum can also be safe.

Student B: Encourage your friend to consider that although iron pans are heavier, they are more durable and safer for health, especially for those looking to save in the long term.

To further address the identified problems, emphasis should be placed on using guiding questions to help students regularly assess the clarity of the connections between their claims and evidence such as "How are physical properties such as thermal conductivity and heat retention of these two materials related to the type of metallic bonding they possess?" "If the goal is to cook food that requires high and sustained heat, such as baking or stewing, which material would you

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

recommend for Noon to use? Justify your answer using the relevant properties of the material." "How is the fact that iron does not react with food related to the chemical inertness of metals, and is this property important for cooking safety" This question encourages students to think about the evidence supporting their conclusion. Students are expected to explain their observations, such as electrical conductivity in solution or solubility in different solvents. In the argument-driven inquiry instructional model, the emphasis is on having students analyze and reason through the evidence themselves, with the teacher acting as a facilitator. This process requires time and continuous practice. Regarding alternative claims and supportive counterarguments, students may be encouraged to create their own learning materials using designated equipment. This approach aims to enhance their analytical skills, strengthen their ability to connect evidence with claims, and facilitate the identification of differences between claims for argumentation. Each component of this process requires sufficient time for skill development and reinforcement. The summary of the development of scientific argumentation skills after receiving instruction through argument-driven inquiry, upon completion of the operational cycles, is presented in Table 7.

Table 7: The individual levels of scientific argumentation skills across all three operational cycles

ID	Cycles		
	1	**2**	**3**
1	Moderate	Low	Moderate
2	Low	Very low	Moderate
3	Moderate	Moderate	Very good
4	Moderate	Good	Moderate
5	Good	Very good	Very good
6	Moderate	Moderate	Moderate
7	Moderate	Moderate	Moderate
8	Good	Very good	Very good
9	Low	Moderate	Moderate
10	Low	Good	Good

From Table 7, it can be observed that ten students showed an improvement in their scientific argumentation skills in the third operational cycle. However, in the second operational cycle, two students demonstrated a decrease in their scientific argumentation skills, but this improved again in the third operational cycle and some students' argumentation skills remained stable. This decline occurred because the students were unable to provide supportive argument and counter arguments, which led to a decrease in their overall scores and, consequently, their ability to argue scientifically. Additionally, the content in the second operational cycle, which focused on topics such as writing chemical formulas, naming covalent compounds, bond length, bond energy, molecular shape, and intermolecular forces in covalent, was complex and difficult to understand, requiring more time to study. In line with the research by Tongprapai, et al. (2016) found that some students' argumentation skills remained stable or needed improvement due to insufficient time for studying the content. Additionally, students believed they had sufficient knowledge about the issues used to respond to the given situations. When examining the average scores of each argumentation component across the three operational cycles, the results show the developmental progress as illustrated in Figure 2.

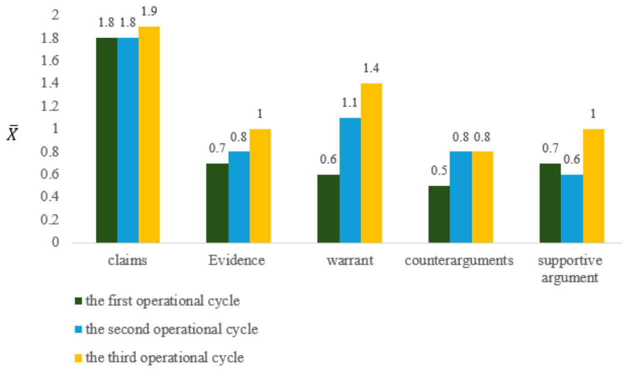


Figure 2: The results of the development of the components of scientific argumentation skills.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

From Figure 2, It was found that, following the instructional intervention, all components of students' argumentation showed improvement. The highest score was in the claim ($\bar{x}$ = 1.9), followed by warrant ($\bar{x}$ = 1.4), evidence ($\bar{x}$ = 1.0), supportive arguments ($\bar{x}$ = 1.0), and counter arguments ($\bar{x}$ = 0.8), respectively. This indicates that students demonstrated strong abilities in presenting their claims and gradually developed structured warrant, evidence, counterargument, and supportive argument. These findings align with the research conducted by Suwannatrai & Sangpradit (2023), which found that students' average scientific argumentation skills after instruction were significantly higher than before instruction at a .05 significance level. Students scored the highest in the claim component because identifying claims involves stating answers based on their investigations. In argumentation situations, students are provided with information or guiding questions, which help them clearly formulate their claims, leading to higher scores in this aspect. This finding is consistent with the study by Sampson, Grooms & Walker (2012), which defines a claim as a conclusion, prediction, explanation, or other response to a given question.

The warrant component showed a significant improvement among students. This development can be attributed to the learning activities in the exploration and investigation stages, where questions were used to stimulate students' critical thinking and encourage them to express their opinions. Additionally, students engaged in discussions to clarify doubts, and instructional media were provided to facilitate inquiry-based learning, enabling students to better understand and visualize concepts. This finding is consistent with the study by Grooms, et al. (2016), which emphasizes that asking questions during inquiry-based learning, questioning the methods used to obtain answers, providing guidance and support, and explaining or offering directions for students' uncertainties can effectively enhance their ability to provide warrant.

In the aspect of evidence, the exploration phase of the learning activity is when students investigate and gather evidence to support their claims. The teacher integrates instructional materials into the inquiry process to help students use them as evidence to substantiate their claims. Examples of these materials include the Lewis structure puzzle board, molecular shape models, and the Born-Haber cycle diagram. This is consistent with the findings of Sampson & Gleim (2009) stated that preparing essential materials for inquiry-based learning-such as samples, models, slides, and experimental equipment-facilitates the collection of evidence to support claims. However, providing instructional materials alone is often insufficient, as some students may encounter difficulties in interpreting or effectively applying these resources. Therefore, implementing instructional support is essential. Teachers can provide scaffolding through activities such as modeling how to analyze information from diagrams, using guiding questions to link observations to scientific principles, or incorporating graphic organizers. These strategies help strengthen students' ability to purposefully use evidence. For example, asking questions like "What does this model represent?" or "How does this evidence support your claim?" can assist students in making meaningful connections between the materials and underlying scientific concepts.

In the aspects of supportive arguments and counter arguments, students engage in temporary argument construction and argumentation activities. In the temporary argument construction phase, each student group summarizes their findings from the inquiry, with the teacher providing guidance to stimulate students' analytical thinking and to help them make connections between evidence and warrant. The teacher also reviews the arguments of each group to identify differences that lead to the argumentation phase. During the argumentation activity, the teacher prepares questions to stimulate discussion and encourage students to think critically. The discussion is controlled to stay on topic, and the key points from each group are summarized. This approach aligns with Sampson & Gleim (2009), which stated that when providing alternative arguments, it is essential to review students' arguments, stimulate critical thinking to find counter arguments, and control the discussion to stay focused on the key points.

However, in terms of using evidence, counter arguments, and supportive arguments, the development was not as expected. This is because some students still lacked skills in analytical thinking, systematic problem-solving, and critical thinking. Walker & Sampson (2013) pointed out that students must be able to evaluate the accuracy of information and analyze what constitutes reliable evidence to construct well-reasoned arguments. Within the argument-driven inquiry framework, students are placed in situations where they must pose questions, conduct investigations, present data, and engage in argumentation with others. This process enables them to

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

learn systematic problem-solving, rather than simply finding the correct answer. Scientific argumentation is therefore a process that inherently relies on analytical thinking, systematic problem-solving, and critical thinking. Without these skills, students will be unable to construct evidence-based arguments, analyze information rationally, or respond to counter arguments effectively.

Moreover, most students lacked strong writing skills, which require time and structured practice to develop. While they could verbally present their group's ideas, they struggled with writing argumentation notes particularly in summarizing and selecting relevant information resulting in brief and underdeveloped explanations, especially regarding evidence, counter arguments, and supporting points. This aligns with Kamart (2022), who noted that using evidence is the most challenging aspect of argumentation, as verifying reasoning is more complex than stating opinions. Similarly, Sandoval and Millwood (2005) emphasized that effective use of evidence requires a deep understanding of both context and content. To address these difficulties, the researcher implemented instructional scaffolding strategies to support students' gradual development. These included tools such as argumentation boards, chemical models, and survey boards to visualize relationships between claims, evidence, and data , as well as contextual practices that link scientific concepts to real-world scenarios. The lessons incorporated analytical questioning and group-based activities as scaffolds to help students build confidence and fluency in constructing evidence-based arguments.

Regarding counterarguments, it was found that students in the second and third operational cycles showed consistent but unchanging development. This may be attributed to the fact that some students often neglected to clearly articulate their peers' differing claims. Instead, they tended to explain why their peers might have responded in a certain way and attempted to persuade them to agree with their own claim. This pattern reflects a lack of analytical skills in examining the question or situation thoroughly. Many students tended to skim through the text, which often led to misinterpretation or omission of key details. Skills such as analytical thinking, reading comprehension, and information synthesis are not developed overnight but require continuous practice and reinforcement. This finding is consistent with Wu & Tsai (2007), who found that students who were unable to construct counter arguments often relied on limited perspectives and tended to focus solely on presenting supportive arguments. These students typically lacked an understanding that effective argumentation involves identifying weaknesses in opposing viewpoints and presenting rebuttals. Potential strategies for development include training students to reason from multiple perspectives, encouraging the use of evidence to shift viewpoints, and having students engage with a variety of texts or data before beginning an argument. Additionally, students can be guided to evaluate both their own and their peers' arguments using a checklist that includes whether a counterargument is present. Finally, incorporating reflective writing after argumentation activities can help students articulate why they agree or disagree with reasons.

In terms of supportive arguments, it was found from Figure 1 that although the average score of supported arguments increased from the first operational cycle to third operational cycle, a decline was observed in the second operational cycle. This suggests that the topic of covalent bonding may involve complexities that affect students' ability to construct arguments, as a result, analyzing and incorporating evidence to supported arguments became more challenging. This finding is consistent with Sandoval & Millwood (2005), who noted that students are more effective in using evidence when they have a clear understanding of both the content and the context of the problem. This is consistent with the research by Songsil (2017), which found that most students still lacked the skills to support arguments, especially when faced with counter arguments. Furthermore, it was observed that most students were unable to identify counter arguments and often relied on emotional responses. Providing support arguments is an advanced cognitive process that requires the ability to analyze, synthesize, and evaluate information comprehensively. To enhance student learning, several instructional strategies can be adopted. These include using guiding questions such as "What evidence supports your claim?" or "How do you connect this data to your claim?" to encourage systematic thinking. Students can compare and analyze examples of different arguments to learn how to logically connect claims with evidence. Activities can be designed where students practice using evidence in various contexts to develop a deeper and more flexible understanding for application.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

CONCLUSION AND IMPLICATIONS

The research on enhancing the scientific argumentation skills of grade 10 students on the topic of chemical bonding through argument-driven inquiry revealed that after completing all three operational cycles, students' scientific argumentation skills improved progressively in each operational cycle. By the final operational cycle, three students demonstrated very good argumentation skills, one student showed good skills, and six students displayed moderate skills. When considering the components of argumentation, it was found that students showed development in every aspect. Throughout the third operational cycles, continuous development was observed, particularly in the components of warrant and evidence, while most students were already proficient in identifying claims. This skill development was fostered by the argument-driven inquiry process, which provides a clear structure and encourages students to design experiments, observe phenomena, analyze data, and communicate their findings using scientific reasoning and evidence. The process also promotes discussion, idea exchange, and the practice of analytical thinking, enabling students to distinguish facts from opinions and assess the credibility of information.

The findings revealed that the argument-driven inquiry approach is an effective instructional strategy for promoting students' scientific argumentation skills, reasoning abilities, communication, and collaboration. When systematically integrated into learning activities such as laboratory experiments, group discussions, evidence-based writing, and student presentations provide ongoing opportunities for students to construct and respond to arguments. However, the development of counter arguments and supportive arguments remains limited, as these require higher order thinking skills, including analysis, synthesis, and scientific writing. Although these skills can be cultivated, they demand time, continuity, and structured support from the teacher. Furthermore, the use of component-based assessment for each student in every cycle revealed fluctuations in skill development, particularly in the second operational cycle, where some students' scores noticeably declined. This suggests that the complexity of the content may affect students' ability to counter arguments and supportive arguments. The effectiveness of argument-driven inquiry was also reflected in the integration of creative instructional tools and activities, such as survey boards, argumentation boards, and molecular models, which fostered a classroom environment that encouraged students to share ideas, express their reasoning, and support their claims with evidence. These tools, along with well-designed guiding questions, enabled students to connect data, evidence, and warrant more effectively. To maximize the effectiveness of argument-driven inquiry, teachers must not only understand the core principles of the approach but also be capable of designing aligned activities and learning materials, while cultivating a classroom culture that fosters analytical thinking, evidence-based argumentation, and respectful dialogue among students.

Recommendations for Application

1. Design learning activities aligned with content and student context: Teachers should adapt instructional content to suit students' proficiency levels, particularly in abstract chemistry topics such as chemical bonding. The use of models, visual media, and simulated scenarios is recommended to help learners grasp the overall concepts more clearly and enhance their understanding.

2. Gathering information phase: This phase is critical for argumentation, and teachers must pay special attention to it. Teachers should use questioning techniques to encourage students to express their opinions and emphasize the need for reliable information, as students may lack confidence in the data they have gathered, which could impact the temporary argumentation phase.

3. Constructing arguments phase: At this stage, teachers should design activities that allow all students to observe and present the temporary arguments of each group. This is necessary because some students might not fully grasp or listen attentively. For instance, teachers could use a survey board where students can present and display their arguments at the front of the classroom or have students write their temporary arguments on the board.

4. Argumentation activities phase: This phase is crucial and requires significant attention from the teacher, as students may experience self-doubt or fear of giving incorrect answers, which may hinder their willingness to present and argue with peers. Teachers should review previous group claims and use guiding questions like, "Do you have the other answers?" Students'

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

presentations are not right or wrong but should be based on the evidence they have gathered. This stage may require additional time for students to adjust since they may not be accustomed to such teaching methods.

5. Time management in activities: As this inquiry-based learning activity takes considerable time, teachers should manage activity durations appropriately. The argumentation scenarios should not be too complex if there is limited time for learning.

6. Improving argumentation test design: The research found that students wrote brief responses in the argumentation assessment and often failed to connect or expand their ideas. The test questions should be more specific, such as requiring students to provide at least two reasons or link their opinions to other related issues. Additionally, the data collection methods should align with the nature of the students.

Recommendations for Future Research

1. Sample Size and Contextual Limitations: This study was conducted with a small sample school, which limits the generalizability of the findings to broader educational contexts. Therefore, future research should involve a larger and more diverse student population across various school settings to enhance the reliability and applicability of the results.

2. Duration of Implementation: This study was conducted over only three operational cycles, which may be insufficient to reflect long-term development particularly in the components of counter arguments and supportive counterarguments. It is recommended that future research extends the implementation period or increases the number of operational cycles to explore stable and sustained changes.

3. Investigating factors affecting the stability of argumentation development: While students showed improvement in their argumentation skills, some experienced inconsistent progress with both higher and lower levels. Future research should investigate factors influencing the instability of development, or extend the research duration to track long-term development, which may depend on the school context and individual differences.

4. Investigating the development of counter arguments and supportive counterarguments: This study found that students demonstrated the least improvement in counterargument skills. Moreover, their ability to justify rebuttals declined in the second cycle. Therefore, it is necessary to investigate the factors that influence the development of these skills, or to explore instructional strategies that can effectively enhance students' counterargument abilities.

5. Exploring collaborative skills and problem-solving abilities: This study revealed that, in the development of scientific argumentation skills, students worked in groups and exchanged ideas to solve problems together. Future research should explore how argument-driven inquiry can foster collaborative skills or problem-solving abilities.

REFERENCES

Amelia, D. R., Asrial & Effendi-Hasibuan, M. H. (2020). The Effectiveness of Argument-Driven Inquiry in Promoting Students' Argumentation Skills About Colloids. *Advances in Engineering Research,* 205(1): 328-335.

Amielia, S. D., Suciati & Maridi. (2018). Enhancing Students' Argumentation Skills Using an Argument Driven Inquiry-Based Module. *Journal of Education and Learning (Edulearn)*, 12(3): 464-471.

Celep, N. D. (2015). *The Effects of Argument-Driven Inquiry Instructional Model on 10th Grade Students' Understanding of Gases Concepts (Doctoral Dissertation).* Türkiye: Middle East Technical University.

Erduran, S. (2019). *Argumentation in Chemistry Education: Research, Policy, and Practice*. Retrieved January 2024 from https://doi.org/10.1039/9781788012645.

Janhom, P., & Jantrasee, R. (2019). Grade 11 Students' Scientific Argumentation Learned Using Argument-Driven Inquiry in Chemistry Laboratory. *Journal of Learning Innovation and Technology*, 5(1): 1-36.

Jantarakantee, E. (2016). Instruction for Promoting Argumentation Skill in Science Classroom. *Journal of Yala Rajabhat University,* 11(1): 217-232.

Kamart, P. & Srisa-ard, O. W. (2022). Implementing Argument-Driven Inquiry Approach for Developing Grade 12 Students' Ability to Enhance Scientific Argumentation on The Topic of Polymer. *Rajabhat Maha Sarakham University Journal,* 16(3): 76-87.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Lin, S. & Mintzes, J. J. (2010). Learning Argumentation Skills Through Instruction in Sociocentric Issues: The Effect of Ability Level. *International Journal of Science and Mathematics Education*, 8(6): 993-1017.

Maneetup, S., & Harnsoongnoen, S. (2023). The Effect of Open Learning on Science Argumentation Skills Among Grade 11 Students. *Journal of Mahasarakham Rajabhat University*, 17(1): 78-88.

Ministry of Education. (2008). *Basic education core curriculum B.E. 2551*. Thailand: Ministry of Education.

Mueang Mahawichanukool School. (2022). *Self-assessment report (SAR) for the academic year 2022* Thailand.

OECD. (2021). Are 15-Year-Olds Prepared to Deal with Fake News and Misinformation. *PISA in Focus*, (113), Paris: OECD Publishing.

Office of the Basic Education Commission. (2022). *Basic Education Development Plan B.E. 2566 –2570*. Retrieved January, 2024 from https://www.obec.go.th /archives/813787.

Özelma & Seyhan, H. G. (2022). Effect of Argumentation Based Learning on Science Achievement and Argumentation Willingness: The Topic of "Particulate Nature of Matter". *Bulletin of Education and Research*, 44(2): 31-50.

Phararanat, W., & Nuangchalerm, P. (2018). Reasoned Argumentation: A Skill for Surviving in the 21St Century. *Journal of Humanities and Social Sciences Mahasarakham University*, 37(2): 174-181.

Rusmini, R, Suyono, & Agustini, R. (2021) Profile of Argumentation Ability of Undergraduate Students in Chemistry Education Based on Non-Routine Problems. *E3s web of conferences*, 328(7): 06007.

Sampson, V. & Walker, J. P. (2012). Argument-Driven Inquiry as a Way to Help Undergraduate Students Write to Learn by Learning to Write in Chemistry. *International Journal of Science Education*, 34(10): 443-1485.

Songsil, W. & Faikhamta, c. (2017). Grade 10 Students' Scientific Argumentation in Socio-Scientific Issues. *Rajabhat Maha Sarakham University Journal*, 11(3): 175-184.

Suwantrai, T. & Sangpradit, T. (2023). Development of 8th Grade Students' Scientific Argumentation Skills Through Argument-Driven Inquiry with Higher Order Questions in Energy Resources Topic. *Silpakorn Educational Research Journal*, 15(1): 282-298.

Tongprapai, K., Pitiporntapin, S., Shinnasin, K. & Jamjai, O. (2016). Development of Grade 8 Students' Argumentation Skill in Nutrients and Life Unit Using Socio-Scientific Issue (SSI)–Based Teaching. *Journal of Research Unit on Science, Technology and Environment for Learning*, 7(1): 48-61.

Walker, J. P., & Sampson, V. (2013). Learning to Argue and Arguing to Learn: Argument-Driven Inquiry as a Way to Help Undergraduate Chemistry Students Learn How to Construct Arguments and Engage in Argumentation During a Laboratory Course. *Journal of Research in Science Teaching*, 50(5): 561–596.

William, A. S., & Millwood, K. A. (2005). The Quality of Students' Use of Evidence in Written Scientific Explanations. *Cognition and Instruction*, 23(1): 23–55.

Wu Y. T. & Tsai C. C. (2007). High School Students' Informal Reasoning on a Socio-scientific Issue: Qualitative and quantitative analyses. *International Journal of Science Education*, 29 (9): 1163-1187.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

International Journal of Science Education and Teaching
Vol. 4, No. 2, pp. 93-105, May. – Aug. 2025
http://doi.org/10.14456/ijset.2025.07

Enhancing Critical Thinking Ability and Learning Achievement through a Science, Technology, and Society (STS) Approach for Grade-10 Biology on the Topic of the Chemistry Basis of Life

Nattinan Weawkeaw[1], and Natchanok Jansawang[2]
[1]*Master Science Education Program, Rajabhat Maha Sarakham University, Thailand*
[2]*Faculty of Science, Rajabhat Mahasarakham University, Thailand*
*Email: 668010300103@rmu.ac.th

Received: 17 Mar. 2025 Revised: 5 Jun. 2025 Accepted: 8 Jun. 2025

Abstract. This study aimed to 1) compare the critical thinking ability of students before and after applying the Science, Technology, and Society (STS) learning approach, and 2) compare students' academic achievement on the topic "Chemistry Basis of Life" with the 70% criterion. The sample group consisted of 40 Grade-10 students from Phadungnaree School in the first semester of the 2024 academic year, selected using cluster sampling. Research instruments included: 1) six STS-based lesson plans over 18 hours, evaluated as highly appropriate (mean scores = 4.31–4.33, S = 0.54–0.58); 2) a Critical Thinking Test comprising 12 situational scenarios with 30 multiple-choice items (difficulty = 0.40–0.73, discrimination = 0.20–0.47, reliability = 0.82); and 3) an Academic Achievement Test with 40 multiple-choice items (difficulty = 0.43–0.73, discrimination = 0.23–0.43, reliability = 0.76). Data were analyzed using mean, standard deviation, percentage, One-Sample t-test, and Normalized Gain (<g>). The results revealed that: 1) students' critical thinking ability significantly improved after STS learning, with an overall normalized gain (<g>) score of 0.58, which is considered a moderate level. When analyzing the improvement in each subskill of critical thinking, it was found that all aspects showed a moderate level of gain. The <g> descending order were as follows: comprehension (<g> = 0.66), identifying assumptions (<g> = 0.63), deductive reasoning (<g> = 0.62), evaluating arguments (<g> = 0.52), and drawing inferences (<g> = 0.49). And 2) students' academic achievement was significantly higher than the 70% criterion at the .05 significance level. The findings suggest that STS-based learning enhances both critical thinking and academic performance. It is recommended that future studies explore its integration with problem-solving, creativity, and teamwork development to support diverse learners and promote real-world application of scientific knowledge.

Keywords: Critical thinking ability, science, technology and society (STS), academic achievement, Chemistry as the Basis of Life

INTRODUCTION

In the context of rapid global changes, education systems must adapt to develop students with essential 21st-century skills. Thailand's 20-Year National Strategy prioritizes foundational citizenship values and the development of core competencies, including the 3Rs (Reading, Writing, and Arithmetic) and 8Cs: Critical Thinking and Problem Solving, Creativity and Innovation, Cross-

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

cultural Understanding, Collaboration and Teamwork, Communication and Media Literacy, Computing and ICT Literacy, Career and Learning Skills, and Compassion (Office of the Education Council Secretariat, Ministry of Education, 2014). Aligned with the 2024 workforce development policy, which aims to enhance adaptability and reduce unemployment, these competencies support the country's goal of improving educational quality and student potential. Science education is essential in this mission, promoting students' ability to integrate knowledge, apply learning to real-world situations, and act responsibly toward society and the environment (Lomsombut, 2017).

Critical thinking is a vital 21st-century skill, particularly amidst rapid societal and technological change. It enables students to analyze information logically, distinguish facts from opinions, assess information validity, evaluate source reliability, and make informed decisions based on data analysis. The process typically involves gathering information, asking critical questions, and evaluating potential solutions (Herrity, 2023). According to Watson and Glaser (1964), critical thinking encompasses five key aspects: Inference (judging and classifying the probability of conclusions), Recognition of Assumptions (identifying underlying assumptions), Deduction (drawing logical conclusions), Interpretation (weighing evidence to assess conclusions), and Evaluation of Arguments (distinguishing valid reasoning). These skills promote systematic analysis and support the application of thoughtful reasoning in everyday life (Facione, 2015). Moreover, critical thinking helps students synthesize information from diverse sources, leading to deeper understanding and effective application in both academic and real-world contexts (Paul and Elder, 2008).

Making connections between various elements and scientific issues and engaging in reasoned scientific argumentation requires critical thinking. According to the latest PISA (Program for International Student Assessment) results in 2022, conducted by the Organization for Economic Co-operation and Development (OECD), Thailand's average scores were 394 in mathematics, 379 in reading and 409 in science. Compared to PISA 2018, Thailand's average scores decreased in all three areas, with mathematics dropping by 25 points, and science and reading declining by 17 and 14 points, respectively. This reflects problems in Thai students' analytical thinking, critical thinking, and rational data evaluation ability. This aligns with Thailand's educational quality issues as reflected in Ordinary National Educational Test (O-NET) results. According to the National Institute of Educational Testing Service (2023), the average O-NET scores for Grade 12 students nationwide in the 2021 academic year were below 50 points in all subjects: Thai Language (44.90), Social Studies (33.00), English (23.44), Mathematics (21.61) and Science (28.08). Considering the National Institute of Educational Testing Service's assessment criteria, which sets 50-64 points satisfactory and 65 points and above as good, these results indicate that the 2021 O-NET scores for Grade 12 still require improvement and continued educational quality development.

Based on an investigation into the root causes of this issue at the school level, they stem from an education system that emphasizes memorization over analytical thinking. Students are unfamiliar with questioning, analyzing data, and reaching conclusions independently. Additionally, educational, and social environmental factors affect students' critical thinking problems. Families and communities prioritize rote learning over encouraging students to think analytically about various media. In today's environment, where genuine and false information intermingle, students lack skills in filtering information and evaluating its reliability (Office of the Basic Education Commission, 2006). Teaching methods that promote students' critical thinking abilities will make instruction more effective, enabling students to think analytically, seek knowledge, and develop their own problem-solving approaches (Soodsane, 2018). Based on the researcher's survey, it was found that the academic achievement of Grade-10 students at Phadungnaree School in the 2023 academic year declined to 68%, which was below the expected criterion of 72% (Phadungnaree School, 2023) This decline reflects a lack of critical and analytical thinking skills, which can be attributed to several factors. These include a teaching system that emphasizes rote memorization over analysis and synthesis, as well as limited opportunities for students to practice questioning and engage in evidence-based reasoning. Consequently, students face difficulties distinguishing facts from opinions. Furthermore, the current information landscape is saturated with diverse content, including both factual and misleading information. The lack of skills in evaluating sources leads students to believe in unsupported or inaccurate information more readily. Therefore, to enhance

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

students’ critical thinking skills and address the issue of declining academic performance, it is essential to adapt teaching methods to better align with student contexts and emphasize instructional approaches that promote analytical thinking. One such approach is the Science, Technology, and Society (STS) model, which fosters learning through the integration of real-world issues with scientific and technological knowledge. In evaluating academic achievement, the researcher set the 70% threshold as the standard criterion. This decision is based on the guidelines of the Basic Education Core Curriculum B.E. 2551 (2008) and the criteria established by the National Institute of Educational Testing Service (NIETS, 2023), which classify scores in the range of 70–74% as indicative of a “good” level of learning performance. Therefore, using this criterion provides a meaningful reference to determine whether students have attained the desired learning outcomes at a satisfactory level.

The Science, Technology, and Society (STS) approach connects social issues with science and technology, promoting effective learning through real-life situations. This study follows Carin’s (1997) five-stage model: 1) Search, 2) Solve, 3) Create, 4) Share, and 5) Action, which engages students by linking technology, social issues, and context, fostering deeper understanding (Yuenyong et al., 2007). STS supports Constructivist theory by helping students relate new knowledge to prior experiences, while promoting critical thinking and addressing scientific, technological, social, environmental, and ethical dimensions (Pimchan & Samranwanich, 2014; Kowtrakul, 2016). It encourages creative problem-solving, argumentation, and reflective evaluation, improving academic achievement (Mulyanti et al., 2021; Yager, 1993). Despite its widespread use to improve attitudes and performance, research on STS’s impact on scientific reasoning and problem-solving at the secondary level is limited (Boesdorfer & Lorsbach, 2014). In Thailand, most STS studies focus on theory (Wattanakasiwich & Ananta, 2010). One key topic in secondary science is "The Basic Chemistry of Life," which is part of the "Substances and Their Properties" section in the Basic Education Core Curriculum B.E. 2551 (Office of the Basic Education Commission, 2008). This content, which forms the basis for understanding biological components and biochemical processes, is often difficult for students due to abstract concepts and memorization-based instruction (Yager & Akcay, 2010). Integrating STS into this topic can help students connect knowledge to real-life situations, understand social and environmental impacts, and develop critical thinking, aligning with curriculum goals and fostering 21st-century skills. This study aims to develop and assess STS-based learning activities to enhance scientific reasoning and problem-solving among Grade-10 students.

In this research, the researcher has chosen the STS (Science, Technology, and Society) Approach model based on Carin (1997) concept, aiming to study critical thinking abilities and academic achievement in Biology, specifically regarding Chemistry as the Basis of Life, among Grade-10 students. In this teaching approach, the instructor serves as a learning process facilitator and allows students’ opportunities to develop critical thinking abilities, research skills, and teamwork through activities emphasizing problem-solving and developing understanding of basic Chemistry of living things found in daily life and its practical applications. This is intended to make the teaching-learning process beneficial and aligned with current and future educational needs, with potential for future educational development.

RESEARCH OBJECTIVES

1. To study critical thinking abilities before and after implementing instruction based on the Science, Technology, and Society (STS) approach.
2. To compare the learning achievement on the topic of " Chemistry as the Basis of Life" of Grade-10 students against the 70% criterion.

METHODOLOGY

The methodology section of the document describes the research design and procedures used to study the effectiveness of teaching in enhancing critical thinking abilities including the analysis of students' academic achievement compared to the 70% criteria.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Population and Sample

The study population comprised 200 Grade-10 students from five mixed-ability classrooms at Phadungnaree School, Mahasarakham, Thailand, during the first semester of the 2024 academic year. A cluster random sampling technique was employed to select a sample of 40 students, with the classroom serving as the unit of random assignment.

Research Tools

The research tools used in this study can be categorized into three types.

1. Learning Management Plan

This study was conducted in accordance with the revised Basic Education Core Curriculum B.E. 2551 (A.D. 2008), updated in 2017 (B.E. 2560), focusing on the subject Additional Science – Biology 1, specifically under the strand The Chemical Basis of Life for Grade-10 students. This content aligns with Learning Standard 1 of the Science Learning Area, which emphasizes understanding the nature of living things and life processes.

The learning management plan follows the Science, Technology, and Society (STS) approach, designed to enhance teaching and learning (Table 1). In this case study, it was developed for a biology course on "Chemistry as the Basis of Life" for Grade-10 students. The six lesson plans were implemented with a total duration of 18 hours. The learning management plan was indicated as highly appropriate with an average rating ranging ("$\bar{x}$") from 4.31 to 4.33 and standard deviation (S) between 0.54 to 0.58.

Table 1. Learning Management Plan

Plan	Content STS	hours
The Chemical Basis of Life	Understanding atoms, elements, compounds, and water is fundamental to recognizing the composition of matter and making informed choices in daily life—such as selecting safe products, consuming food, and medicine wisely, and choosing clean water. It also raises awareness of the environmental and health impacts of chemical use in agriculture, promoting responsible decision-making.	3
Carbohydrates	Carbohydrates are the body's primary energy source, essential for supporting daily activities. Choosing slow-digesting carbohydrates and consuming them in appropriate amounts helps maintain a healthy weight and reduces the risk of chronic diseases.	3
Proteins	Protein plays a vital role in growth, cell repair, muscle development, and immune function. Consuming an adequate amount of protein promotes good health, while excessive intake may negatively affect body function.	3
Lipids	Fat plays a vital role in providing energy for the body; however, excessive intake can lead to health problems. Understanding how fat functions and accumulates in the body supports better health management, including choosing healthy fats and moderating consumption.	3
Nucleic Acids	Nucleic acids, such as DNA, play a vital role in the inheritance of genetic traits and are essential for personal health management, particularly in the prevention of genetic diseases. Understanding DNA contributes to both everyday health awareness and advancements in medical science.	3
Chemical Reactions in Living Cells and Enzymes	The study of biological processes, such as digestion and enzyme function, is crucial for understanding the factors that influence the body's efficiency. Making informed choices regarding healthy food and careful use of chemicals directly impacts personal health and helps mitigate long-term environmental effects. Awareness of these factors is essential for the well-being of individuals and society.	3

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

The content of this research was based on the Grade-10 Biology curriculum, under the topic "The Chemical Basis of Life," with a total of 18 instructional hours, comprising the following subtopics.

The learning management plan was based on the Science, Technology, and Society (STS) approach, following the instructional model proposed by Carin (1997: 27–28), which comprises five key steps. A series of biology lesson plans were developed under the topic "Chemistry as the Basis of Life" as follows:

- Search – Students explore their prior knowledge and express their curiosity by identifying what they want to learn. Their ideas, questions, and problems of interest are categorized to guide the learning process.
- Solve – Each group of students selects a specific question or problem they wish to investigate. They then formulate an action plan to conduct research and seek answers related to subtopics within the unit.
- Create – Students synthesize information gathered from various sources to draw conclusions and summarize the answers to their initial questions or problems. They also design methods to present their findings effectively.
- Share – Each group presents their research findings and solutions to the class. This stage involves discussion and exchange of ideas, promoting collaborative learning and reflection.
- Act – Students apply the knowledge they have acquired through practical activities both inside and outside the classroom, reinforcing learning through real-world application.

2. Critical Thinking Test (CTT)

The Critical Thinking Test (CTT) is a multiple-choice assessment tool developed to measure students' critical thinking skills based on the theoretical framework of Watson and Glaser (1964). The test consists of 30 items, equally distributed across five core dimensions of critical thinking: (1) Inference, (2) Recognition of Assumptions, (3) Deduction, (4) Interpretation, and (5) Evaluation of Arguments. Each item was constructed based on real-life situational scenarios relevant to science learning, aiming to assess students' ability to apply critical thinking in authentic contexts.

The development process began with the drafting of 40 items, each targeting three of the five specific dimensions of critical thinking. These items were then reviewed for content validity by three experts in science education and educational measurement. Revisions were made in response to expert feedback to improve clarity, appropriateness, and alignment with the test objectives. All items were assessed using the Item-Objective Congruence (IOC) method, and each received an IOC score of 1.00, indicating unanimous agreement on their relevance to the intended constructs.

Following content validation, the test was pilot tested with 30 Grade-10 students possessing similar characteristics to the target population. Item analysis was conducted to ensure psychometric quality. The difficulty index (P) ranged from 0.40 to 0.73, and the discrimination index (D) ranged from 0.20 to 0.47, both within acceptable ranges. The internal consistency reliability, calculated using the Kuder-Richardson Formula 20 (KR-20), was 0.82, indicating a high level of reliability.

3. Academic Achievement Test (AAT)

The Academic Achievement Test (AAT) is a 40-item multiple-choice assessment, with four options per item, developed to evaluate students' understanding of the biology topic "Chemistry as the Basis of Life" following the implementation of the instructional intervention. The test was constructed based on behavioral learning objectives and guided by Bloom's Taxonomy, ensuring coverage of cognitive levels ranging from knowledge to evaluation.

The test items were developed in alignment with the core curriculum content and the specified learning outcomes. Initially, a 50-item test was constructed and subjected to content validity evaluation by three experts to determine the alignment between the test items and the behavioral objectives. The Item-Objective Congruence (IOC) index ranged from 0.33 to 1.00. Items with IOC values below 0.50 were considered for elimination, resulting in the last version comprising 40 items.

Subsequently, the revised test was piloted with 30 students who possessed characteristics similar to those of the target population. The item analysis indicated that the test demonstrated acceptable quality, with difficulty indices ranging from 0.43 to 0.73 and discrimination indices ranging from

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

0.23 to 0.43. The reliability of the test, calculated using the Lovett Formula, was found to be 0.76, indicating a high level of internal consistency.

Data Collection

Research Design

This study employed pre-test and post-test experimental research design to measure critical thinking abilities and assess academic achievement.

Data Collection Procedures

1. Permission and Data collection: A formal request was submitted to the administration of Phadungnaree School during the first semester of the 2024 academic year to seek approval for conducting the experiment and collecting data.

2. Student Orientation: Students were informed about the instructional approach based on the STS (Science, Technology and Society) concept for the biology unit, " Chemistry as the Basis of Life."

3. A pre-test was conducted to assess the critical thinking abilities of the students.

4. The experiment was conducted using lesson plans based on the Science, Technology and Society (STS) approach in a biology course on " Chemistry as the Basis of Life ". A total of six lesson plans were implemented over 18 hours.

5. Post-tests: Upon completion of the learning units, students were administered post-tests to measure both academic achievement and critical thinking abilities.

6. Data Analysis: All collected data were analyzed using statistical methods to draw conclusions and summarize the experimental results.

Data Analysis

The researcher analyzed the data using statistical software. The following procedures were conducted.

1. Critical Thinking Abilities: Mean and standard deviation were calculated to compare the pre- and post-test scores. A normalized gain (<g>) test was employed to assess the actual increase in students' learning. The normalized gain is calculated as the ratio of the actual gain in percentage points from the pre-test to the post-test to the maximum possible gain. The normalized gain was categorized into three levels:

High gain: <g> ≥ 0.7

Moderate gain: 0.7 > <g> ≥ 0.3

Low gain: 0.0 ≤ <g> < 0.3

2. Academic Achievement: Mean, standard deviation, and percentage were calculated to describe the post-test scores in biology. A one-sample t-test was used to compare the mean post-test score to a criterion of 70%. The academic achievement scores were interpreted according to the assessment criteria shown in Table 2.

Table 2. Assessment Criteria

Score Range (%)	Indicates
80–100%	Excellent
70–79%	Good
65–69%	Fairly Good
60–64%	Satisfactory
55–59%	Moderate
50–54%	Minimum Acceptable
50–54%	Below Minimum Standard

Note. Adapted from *Guidelines for Learning Assessment and Evaluation* (pp. 22–23), by Office of the Basic Education Commission, n.d., retrieved May 10, 2025, from https://sgs.bopp-obec.info/menu/data/ระเบียบงานวัดผล.pdf.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

RESULTS

The comparison of critical thinking abilities before and after learning through the Science, Technology, and Society (STS) approach of the target group both before and after the STS-based learning approach implementation were done. A 30-item multiple-choices critical thinking test evaluated five aspects: 1) The ability to summarize and infer, 2) The ability to identify preliminary agreements, 3) The ability to deduce, 4) The ability to interpret, and 5) The ability to evaluate arguments. The test average score was calculated and converted into percentages. The results indicated that all 30 students demonstrated an improvement in critical thinking abilities after participating in STS-based learning. The data were analyzed using the Normalized Gain statistic (<g>), focusing on both individual progress and the average N-gain of critical thinking abilities scores before and after the STS approach among Grade-10 students. The findings are presented in Table 3 and Table 4

Table 3. Percentage, average scores, and average N-Gain (<g>) of critical thinking abilities assessment before and after learning through the STS approach for individual grade-10 students

No.	Scores (%)		<g>	Level	No.	Scores (%)		<g>	Level
	Pretest	Posttest				Pretest	Posttest		
1	45.0	67.5	0.42	Moderate	21	47.5	65.0	0.55	Moderate
2	50.0	70.0	0.40	Moderate	22	45.0	70.0	0.83	High
3	50.0	75.0	0.75	High	23	47.5	75.0	0.55	Moderate
4	52.5	70.0	0.44	Moderate	24	42.5	60.0	0.54	Moderate
5	47.5	75.0	0.46	Moderate	25	47.5	70.0	0.82	High
6	32.5	57.5	0.51	Moderate	26	37.5	82.5	0.60	Moderate
7	50.0	72.5	0.60	Moderate	27	52.5	70.0	0.78	High
8	50.0	72.5	0.64	Moderate	28	30.0	75.0	0.66	Moderate
9	60.0	92.5	0.66	Moderate	29	35.0	70.0	0.75	High
10	50.0	85.0	0.30	Moderate	30	40.0	45.0	0.29	Low
11	50.0	85.0	0.64	Moderate	31	45.0	57.5	0.25	Low
12	47.5	75.0	0.63	Moderate	32	55.0	90.0	0.78	High
13	50.0	85.0	0.50	Moderate	33	47.5	75.0	0.55	Moderate
14	57.5	82.5	0.43	Moderate	34	37.5	55.0	0.27	Low
15	45.0	80.0	0.46	Moderate	35	32.5	80.0	0.82	High
16	52.5	80.0	0.56	Moderate	36	27.5	72.5	0.53	Moderate
17	45.0	87.5	0.73	High	37	32.5	70.0	0.65	Moderate
18	37.5	77.5	0.53	Moderate	38	35.0	80.0	0.56	Moderate
19	52.5	77.5	0.33	Moderate	39	40.0	85.0	0.78	High
20	57.5	77.5	0.63	Moderate	40	30.0	82.5	0.78	High
average Pre-test = 57.75					average Post-test = 82.50				
average n-gain			0.59		Moderate				
Number of students: 10			> 0.7		High				
Number of students: 27			≥ 0.3 ≤ 0.7		Moderate				
Number of students: 3			< 0.3		Low				

From Table 3, the analysis of pre-learning scores revealed that the students' average critical thinking ability was 57.75%. After learning through the STS approach, the average increased to 82.50%. Furthermore, the analysis of progress in critical thinking abilities using the Normalized-gain (n-gain) method showed that 10 students (25%) achieved high progress (n-gain > 0.70) with an average n-gain of 0.80, 27 students (67.5%) demonstrated moderate progress (n-gain between 0.30–0.70) with an average of 0.53, and 3 students (7.5%) showed low progress (n-gain < 0.30) with an average of 0.27.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

The overall average n-gain for all Grade-10 students was 0.59, categorized as Moderate. This suggests that the STS-based learning approach facilitated notable progress in critical thinking abilities for most students, though some require additional support to further enhance their learning outcomes.

Table 4. Percentages, average scores, and average N-Gain (<g>) by component of critical thinking abilities assessment before and after learning through the STS approach

Critical Thinking Objectives by Aspect	Number of Students Who Answered Correctly (%)		Average Score ($\bar{x}$)		Average N-gain Score (<g>)	Meaning
	Pretest	Posttest	Pretest	Posttest		
The ability to 1. summarize and infer	54.58	76.67	3.28	4.60	0.49	Moderate
2. identify preliminary agreements	55.00	83.33	3.30	5.00	0.63	Moderate
3. deduce	55.42	82.92	3.33	4.96	0.62	Moderate
4. interpret	57.92	85.83	3.48	5.15	0.66	Moderate
5. evaluate arguments	65.83	83.75	3.95	5.02	0.52	Moderate
Overall	58.87	81.83	3.19	4.90	0.59	Moderate

Based on Table 4, when analyzing the scores from the critical thinking abilities assessment before and after learning, broken down by the components of critical thinking, it was found that the average scores of students improved across all components after the STS-based learning approach. The details are as follows: Component 1: Ability to Summarize and Infer. The average percentage increased from 54.58% to 76.67%, with an average n-gain score of 0.49. Component 2: Ability to Identify Preliminary Agreements. The average percentage increased from 55.00% to 83.33%, with an average n-gain score of 0.63. Component 3: Ability to Deduce. The average percentage increased from 55.42% to 85.83%, with an average n-gain score of 0.62. Component 4: Ability to Interpret The average percentage increased from 57.92% to 85.83%, with an average n-gain score of 0.66. And component 5: Ability to Evaluate Arguments The average percentage increased from 65.83% to 83.75%, with an average n-gain score of 0.52.

Comparison of Academic Achievement in Biology on the Topic of “Chemistry as the Basis of Life” using the Science, Technology, and Society (STS) approach against the 70% criterion were assessed using a 40-item multiple-choices test covering five domains: knowledge recall, understanding, application, analysis, and evaluation. The scores were analyzed using a one-sample t-test to compare the results against the 70% criterion, as shown in Table 5.

The results from Table 5, analyzed by using the one-sample t-test, revealed that the academic achievement of Grade-10 students after learning through the STS approach on the topic of "Chemistry as the Basis of Life" was significantly higher than the 70% criterion at the .05 significance level.

Table 5. Comparison of Academic Achievement After Learning Through Science, Technology, and Society (STS) Approach on the Topic of " Chemistry as the Basis of Life " Among Grade-10 Students

Assessment	**Number of Students (n)**	**Full Score**	**Average Score ($\bar{x}$)**	**Standard Deviation (S.D.)**	**70% criterion**	**df**	**t-value**	**Sig 1-tailed**
Post-test	40	40	28.9	3.26	28	39	1.74*	.04

(*significant at the .05 level)

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

DISCUSSION

1. The Impact of STS-based Learning on Critical Thinking Abilities

The research findings indicate that Science, Technology, and Society (STS)-based learning plays a significant role in enhancing students' critical thinking abilities. The average n-gain score was found to be at a Moderate level (0.58), with specific components such as interpretation and preliminary agreement identification achieving higher n-gain scores of 0.66 and 0.63. According to the instructional approach that emphasizes students' connection to real-world problems, analytical questioning, and active participation, learning activities were designed based on the Science, Technology, and Society (STS) framework, consisting of the following five phases: 1) Search – This phase enhances students' ability to identify initial assumptions, as they must distinguish between relevant and irrelevant information and determine what is essential for problem-solving. It also supports the development of interpretation skills, as students are required to assess and evaluate the credibility of information from various sources. 2) Solve – This phase promotes deductive reasoning, as students must logically connect the gathered data to formulate rational answers within given scenarios, using principles of logical reasoning in their decision-making. 3) Create – This stage contributes to the ability to draw inferences, as students synthesize their research findings and connect different facts to develop coherent and reasonable conclusions that relate directly to the studied issue. 4) Share – Presenting information in this phase fosters students' ability to evaluate arguments. They must listen to differing opinions and counterarguments and assess their validity and soundness. 5) Act – The final phase strengthens both inferencing and argument evaluation skills, as students apply their acquired knowledge to real-life situations, aiming to solve problems or drive change based on logical reasoning and outcome-based evaluations. These results congruent with the study of Yager and Akcay (2010) that the STS (Science, Technology, and Society) enhances analytical and argumentative skills as students must integrate information from various sources to evaluate facts. The findings of this study confirm that students show significant development in summarization, referencing, and deductive reasoning. Furthermore, STS learning reduces the limitations of traditional memory-focused approaches by stimulating interest and fostering a broader contextual understanding. This enables students to effectively connect knowledge to real-life social and technological issues. These findings align with Bybee's (1990) research, which shows that learning that integrates science, technology, and society encourages deeper thinking as students analyze diverse situations and pose meaningful questions to address everyday problems. This reflects the importance of designing learning activities that focus on fostering deep understanding and enabling students to apply their thoughts in multifaceted ways.

Additionally, this is consistent with the study by Mulyanti, et al. (2021), which found that the STS approach can effectively stimulate critical thinking and data analysis skills among students. This reflects the effectiveness of connecting scientific knowledge to societal and technological issues, consistent with the findings of this study, which show that STS-based learning design is a powerful tool for developing critical thinking and applying knowledge in complex situations effectively. Thus, STS learning not only stimulates critical thinking and analytical skills but also enhances context-based understanding of societal and technological connections to daily life. Moreover, the average n-gain score was 0.58, which is categorized as a moderate level. Among the students, 27 (67.5% of the sample) had n-gain scores at the moderate level, with an average n-gain of 0.53 for this group. This reflects a satisfactory improvement in critical thinking abilities following the implementation of STS-based learning. However, the research also indicates that some students remain at a moderate to low level in critical thinking, potentially due to factors such as varying levels of foundational understanding or a lack of activities that stimulate deeper thinking. This finding aligns with Cavas's (2011) study, which explored the use of STS in developing analytical skills among secondary school students in Türkiye. While critical thinking abilities improved, tailoring activities to meet the needs of different student groups remained crucial for enhancing the effectiveness of STS learning. This discussion suggests that researchers should consider increasing support and designing more challenging activities to stimulate deeper thinking for students with lower achievement levels.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

In addition to the development of critical thinking skills reflected by the average n-gain score, the STS (Science, Technology, and Society) instructional approach also demonstrates a strong connection to key theoretical frameworks in education, particularly the concept of Constructivism. This theory posits that learners construct new knowledge through interaction with their environment, direct experiences, and reflective thinking (Vygotsky, 1978). The STS model effectively supports this by engaging students in a variety of learning activities such as inquiry-based questioning, group discussions, experimental design, and the evaluation of real-world social and technological issues. Learning through authentic, real-life contexts enables students not only to acquire content knowledge but also to develop critical thinking skills. These skills are fostered through processes of analysis, comparison, logical reasoning, and evidence-based decision-making. This is reflected in the observed improvements in students' abilities to draw inferences and apply deductive reasoning. Saputri, Harahap, and Rosita (2021) found that the STS approach significantly enhances students' critical thinking abilities, as learners are required to connect information from diverse sources and critically evaluate facts within real-world situations. Moreover, the STS approach aligns well with the principles of Active Learning, which emphasize genuine student engagement. Interaction among peers and with the instructor through hands-on activities—such as discussion, experimentation, and small-scale projects—serves as a key factor in promoting deep understanding and analytical thinking, which are essential 21st-century skills (Prince, 2004). Considering these findings, it is evident that the STS approach not only enhances students' academic achievement in quantitative terms but also promotes knowledge construction, positive attitudes, and the development of essential cognitive skills for life in the modern world. Designing learning activities that are appropriately challenging, tailored to students' prior knowledge, and connected to relevant social contexts will further strengthen the effectiveness of STS-based instruction.

2. The learning achievements of students after STS-based learning.

The average learning achievement score was 28.9 out of 40 points, equivalent to 72.25%, which is significantly higher than the 70% criterion (Sig = .04). The t-value obtained from the hypothesis testing was 1.744, indicating that this instructional approach effectively improved learning outcomes. The instructional activities aligned well with Bloom's taxonomy in the following aspects: 1) Knowledge and memory: Students reviewed materials such as documents, videos, slides, or manuals and answered simple questions to assess memory, such as "What are the basic chemical components of living organisms?" Activities such as flashcard games or online quizzes reinforced students' recall of fundamental information, such as basic chemical equations or definitions. 2) Application: Students designed simple experiments, such as testing the chemical properties of substances found in daily life, enabling them to connect knowledge to real-world scenarios. 3) Evaluation: Students wrote essays or engaged in discussions on the pros and cons of using certain chemicals in daily life, allowing them to evaluate information and express reasoned opinions. 4) Analysis: Students compared two chemical compounds, analyzed similarities and differences, and engaged in case studies to identify chemical components and their effects, thus developing skills to discern components and relationships and 5) Understanding: Group discussions were organized where students explained concepts in their own words, such as describing the role of Chemistry in living organisms. Tools like diagrams or mind maps helped students summarize content and demonstrate their understanding of key concepts. These findings are consistent with the study by Yager and Akcay (2008), which found that implementing STS-based learning significantly improved students' academic performance in various domains compared to textbook-based instruction. Students in STS classrooms demonstrated a stronger grasp of fundamental concepts, better application skills, enhanced creative thinking, and a greater capacity to pose complex questions. Moreover, they developed more positive attitudes toward science and showed a higher ability to apply scientific knowledge to real-life situations.

In addition, the implementation of STS-based learning activities reflects the principles of active learning and constructivism, both of which emphasize the role of learners as central agents in the learning process. Students construct their own knowledge through inquiry, questioning, and discussions based on real-world issues (Vygotsky, 1978; Prince, 2004). This approach encourages higher-order thinking skills, as categorized in Bloom's taxonomy (1956), especially analysis,

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

evaluation, and application—skills essential for learners in the 21st century. Furthermore, Yager and Akcay (2008) affirmed that students taught using STS-based instruction demonstrated significantly higher comprehension and application of scientific concepts compared to those taught using traditional methods. This enhancement is attributed to increased opportunities for active engagement, contextual learning, and greater motivation through real-life relevance. However, STS-based instruction also presents certain challenges. These include the complexity of designing activities that appropriately integrate social and technological contexts, and the additional time required compared to conventional methods. This observation aligns with Aikenhead's (2005) assertion that the success of STS instruction depends heavily on the teacher's capacity to meaningfully connect scientific content with students' real-life experiences.

CONCLUSION AND IMPLICATIONS

The research on "Enhancing Critical Thinking Ability and Learning Achievement through a Science, Technology, and Society (STS) Approach for Grade-10 Biology on the Topic of the Chemistry Basis of Life." has summarized the following research findings:

Comparison of students' critical thinking skills before and after learning through the STS approach.

It was found that students' critical thinking skills increased significantly. The average pre-test score was 17.32 out of 30, or 57.75%, while the post-test score increased to 24.75, or 82.50%. The analysis of Normalized Gain (n-gain) revealed an average n-gain of 0.58, which is considered Moderate. Among the students, 25% showed a high level of n-gain (n-gain > 0.70), 67.5% were in the moderate range (n-gain between 0.30-0.70), and 27% had a low n-gain (n-gain < 0.30). When considering specific aspects, the n-gain values were as follows: 1) ability to interpret (n-gain = 0.66), 2) ability to deduce (n-gain = 0.62), 3) ability to identify premises (n-gain = 0.63), which were the highest areas of development. The ability to summarize references (n-gain = 0.49) and assess arguments (n-gain = 0.52) also showed improvement. These results reflect the effectiveness of the STS approach in stimulating critical thinking and connecting content to real-life experiences.

Comparison of students' academic achievement after STS-based instruction on the biology topic "Chemistry as the Basis of Life" against the 70% achievement criterion.

It was found that the average post-test score was 28.90 out of 40, or 72.25%, which is above the set criterion. A statistical test using One-Sample t-test showed a t-value of 1.744 with statistical significance at .05 level (Sig = .04). This indicates that the STS-based learning management significantly contributed to the improvement of academic achievement. The STS approach played a crucial role in designing activities that connect scientific knowledge with technology and societal issues, making the content more meaningful and relevant to the students' daily lives.

Implications for practical

1. Educators should focus on designing activities that promote in-depth thinking and argumentation on real-life issues.

2. The use of technology and online learning resources, such as instructional videos, virtual models, and collaborative learning platforms, should be integrated into the teaching process to enhance student engagement and facilitate effective learning.

Implications for future research

1. Research findings indicate that students demonstrate varying levels of comprehension, with some exhibiting low to moderate critical thinking skills (n-gain < 0.30). To ensure inclusive skill development, future studies should investigate the impact of STS-based learning on teamwork skills, allowing students with stronger comprehension to explain and support the learning of their peers effectively.

2. The study revealed that some students still possess moderate to low critical thinking skills and struggle to connect scientific knowledge with real-world contexts due to differences in comprehension levels and a lack of deep-thinking activities. As a result, future research should explore the integration of STS-based learning with problem-solving and creative thinking skills through activities that blend science, technology, and society. This approach aims to enhance students' creativity and their ability to apply knowledge effectively in real-life problem-solving scenarios.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

REFERENCES

Aikenhead, G. S. (2005). Science-based occupations and the science curriculum: Concepts of evidence. *International Journal of Science Education,* 27(3), 269–273. https://doi.org/10.1080/0950069042000323756

Bloom, B. S. (Ed.). (1956). Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain. Longmans, Green.

Boesdorfer, S. B., & Lorsbach, A. (2014). Assessing the STS approach in science education: Benefits and challenges. *Science Educator*, 23(1), 1–9.

Bybee, R., & Landes, N. M. (1990). Science for life and living: An elementary school science program from Biological Sciences Improvement Study (BSCS). *American Biology Teacher*, 52(2), 92–98.

Carin, A. A. (1997). *Teaching modern science (7th ed.)*. New Jersey: Prentice-Hall, Inc.

Cavas, P. (2011). Factors affecting the motivation of Turkish primary students for science learning. *Science Education International*, 22(1), 31–42.

Facione, P. A. (2015). *Critical thinking: What it is and why it counts*. Insight Assessment.

Herrity, J. (2023). *The importance of training employees: 11 benefits*. Indeed.

Kowtrakul, S. (2016). *Educational psychology* (12th ed.). Bangkok: Chulalongkorn University Press.

Lomsombut, J. (2017). *The study of learning outcomes through the teaching activities based on Science, Technology, and Society (STS) approach on the topic of the human body among Grade 6 students*. Master's Thesis. Mahasarakham: Rajabhat Mahasarakham University.

Ministry of Education. (2022). *Guidelines for assessment and evaluation in primary and secondary education.* Bangkok: Ministry of Education.

Mulyanti, S., Halim, A., Murniati, S., Ilyas, S., Syukri, M., & Mursal, M. (2021). The impact of the science technology society (STS) approach on critical thinking ability and student learning outcomes. *Journal of Physics: Conference Series,* 1882(1), 012026. https://doi.org/10.1088/1742-6596/1882/1/012026

National Institute of Educational Testing Service (Public Organization). (2023). *Summary of the Ordinary National Educational Test (O-NET) results for Grade 12, academic year 2022*.

National Institute of Educational Testing Service (Public Organization). Retrieved March 2023 from https://www.niets.or.th/th/content/view/25620

Paul, R., & Elder, L. (2008). Critical thinking: The nuts and bolts of education. *Optometric Education*, 33(3), 88–91.

Phadungnaree School. (2023). *Self-assessment report (SAR) for the academic year 2023*. Thailand.

Pimchan, O., & Samranwanit, W. (2014). The study of students' understanding of the nature of science in Grade 9 through learning about life and the environment using the Science, Technology, and Society (STS) approach and identifying the nature of science. *KKU Science Journal*, 42(4), 748–760.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Saputri, W. D., Harahap, F., & Rosita, N. T. (2021). The effect of STS (Science-Technology-Society) learning model on students' critical thinking skills. *Journal of Educational Science and Technology*, 7(2), 155–161. https://doi.org/10.26858/est.v7i2.20319

Soodsane, D. (2018). *Supplementary potential process about critical thinking of learners in the 21st century with consistent natural science*. Bangkok: Office of the Basic Education Commission Ministry of Education. [in Thai]

Office of the Basic Education Commission. (n.d.). Guidelines for learning assessment and evaluation (pp. 22–23). Retrieved May 8, 2025, from https://sgs.bopp-obec.info/menu/data/ระเบียบงานวัดผล.pdf

Office of the Education Council Secretariat, Ministry of Education. (2014). *Guidelines for the development of Thai education in preparation for the 21st century*. Bangkok: Prikwarn Graphic Co., Ltd.

Office of the National Education Commission. (2006). *Creative thinker: Educational management manual for who has a talent of high-level thinking skills*. Bangkok: Ratanapornchai. [in Thai]

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

Wattanakasiwich, P., & Ananta, S. (2010). Scientific reasoning ability and attitude toward physics of first-year students. *Chiang Mai University Journal of Natural Sciences,* 9(2), 223–233.

Watson, G., & Glaser, E. M. (1964). *Watson-Glaser critical thinking appraisal manual.* New York, NY: Harcourt, Brace & World.

Yager, R. E., & Tamir, P. (1993). STS approach: Reasons, intentions, accomplishments, and outcomes. *Science Education*, 77(6), 637–658. https://doi.org/10.1002/sce.3730770603PhilPapers+1ERIC+1

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0*.*

Yager, R. E. (1996). Science/Technology/Society as Reform in Science Education. State University of New York Press.
Yager, R. E., & Akçay, H. (2008). Comparison of student learning outcomes in middle school science classes with an STS approach and a typical textbook-dominated approach. *RMLE Online*, 31(7). https://doi.org/10.1940/4476
Yager, R. E., & Akcay, H. (2008). Comparison of student learning outcomes in STS-based and textbook-based science education. *Eurasia Journal of Mathematics, Science and Technology Education*, 4(1), 13–20. https://doi.org/10.12973/ejmste/75304
Yager, R. E., & Akçay, H. (2010). The impact of a science/technology/society teaching approach on student learning in five domains. *Journal of Science Education and Technology*, 19(6), 602–611. https://doi.org/10.1007/s10956-010-9226-7
Yuenyong, C., & Yuenyong, J. (2007). Grade 1 to 6 Thai students' existing ideas about energy. *ICASE Science Education International*, 18(4), 289–298.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

International Journal of Science Education and Teaching
Vol. 4, No. 2, pp.106-125, May. – Aug. 2025
http://doi.org/10.14456/ijset.2025.08

What Are the Factors Influencing Science Learning in the Discovery Model? An Exploration of Issues to Create Innovation

Thoriqi Firdaus[1*], Agum Yuda Septajati[1], Apriana Djara[1], Riski Dewanto[1], Ismail Fikri Natadiwijaya[1], Maryati[1]
[1]*Natural Science Education, Universitas Negeri Yogyakarta, Indonesia*
**Email: thoriqifirdaus.2023@student.uny.ac.id*

Received: 15 May. 2025 Revised: 11 Jul. 2025 Accepted: 14 Jul. 2025

Abstract. The issues in science learning are not solely related to individual factors but involve interacting factors, where both internal factors, such as self-efficacy, motivation, epistemological beliefs, and curiosity, as well as external factors such as learning media and technology readiness, dynamically interact to shape students' perceptions and impact their learning. This study identifies and analyzes the factors influencing school science teaching, focusing on developing innovative strategies to address existing challenges. The research method employed is a mixed-method approach, utilizing Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis to test hypotheses and in-depth interviews to explore the challenges, issues, and expectations of science learning. The findings indicate that curiosity significantly impacts engagement in learning (p-value = 0.003) and learning models (p-value = 0.002), suggesting that students' curiosity enhances their engagement in learning and influences the selection of learning models. Motivation significantly affects learning models (p-value = 0.011), not engagement or media usage. Furthermore, technology readiness plays a significant role in engagement in learning (p-value = 0.002) and learning media (p-value = 0.000), but does not influence the learning model choice. Interviews with teachers also revealed that the primary challenge is providing appropriate media to stimulate students, particularly for challenging topics, and the need for more interactive and real-world problem-based media to support discovery learning more effectively.

Keywords: Discovery learning; self-efficacy; motivation; epistemological beliefs; engagement in learning

INTRODUCTION

Science education plays a pivotal role in its implementation across many schools (Markula & Aksela, 2022), challenges related to the preferences and the gap between the teacher's vision and the vision for science education need further exploration (Penuel et al., 2020). The lack of clear teaching objectives, the absence of a philosophy of science perspective in textbooks, curriculum constraints, and inadequate teacher-specific training (Liu et al., 2023) are factors influencing the quality of science education, necessitating prompt solutions. Educators have also reported challenges in teaching science education, including issues with the students themselves, general conditions, actual teaching practices, and the qualifications of the educators (Barenthien & Dunekacke, 2022). These reports indicate that factors influencing the quality of science education are not only related to

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

curriculum aspects or educational policies (Suprapto et al., 2021) but also to individual student factors such as motivation (Firdaus et al., 2025; Papadakis et al., 2023), self-efficacy (Haatainen et al., 2021), and student engagement in the learning process (Lin, 2021).

Another challenge is that science learning is perceived as highly demanding, making students feel disengaged and unmotivated (Noh et al., 2020). Epistemological beliefs become a significant concern in science learning due to students' limited understanding of how knowledge is acquired and understood (Schommer, 2019). This factor is crucial in determining whether students enjoy or comprehend science education. Students who believe knowledge is fixed and unchangeable are less likely to embrace innovation and interactive, technology-based learning methods (Levin & Wadmany, 2005). This factor is closely linked to students' curiosity, as it can encourage them to actively seek out and learn science content beyond the classroom (Kibga et al., 2021). Curiosity must be stimulated at the outset of learning to promote this exploration.

Curiosity and inquisitiveness can leverage cutting-edge technology to captivate the enthusiasm of both educators and researchers, thereby fostering inquiry-based classroom activities (Ruzaman & Rosli, 2020), which can act as a stimulus for students. However, not all students or teachers can integrate technology into learning. This readiness includes technical skills (Kaushik & Agrawal, 2021), access to adequate devices, and a positive attitude toward using technology in education (Nikolopoulou et al., 2021). This factor requires student involvement in the learning process, as students who actively engage in discussions, experiments, or interactions with learning media tend to have more positive perceptions of the learning process (Cho et al., 2021; Rossi et al., 2021).

Students' perceptions of learning will form a dynamic interaction among various factors (Jansen et al., 2014), and the complexity of this issue can influence science learning. Understanding the relationship between internal factors (motivation and self-efficacy) and external factors (learning media and technology readiness) is crucial, as it contributes to the quality of science education (Swarat et al., 2012). Perception can affect how students view learning, impacting motivation and learning outcomes (Schunk & DiBenedetto, 2020). Positive perceptions of learning media and strategies will encourage students to become more active and engaged in the learning process (Cho et al., 2021). Conversely, if students feel that the media or methods used are irrelevant or uninteresting, they will likely demonstrate lower engagement (Lin, 2021; Yang et al., 2023).

Several previous studies have identified internal and external factors affecting science learning. Britner & Pajares (2006) research shows that laboratory experiences and teacher feedback can influence students' self-efficacy in science. This influence was further corroborated by Tsai et al. (2011), who showed that students' beliefs about science impact their learning approaches. Students' beliefs require visual representations, as Rutten et al. (2012) demonstrated, where PhET simulations effectively supported learning, emphasising physics concepts.

Research on the interaction between internal and external factors was also conducted by Jansen et al. (2014), who explored how students' perceptions of science learning are influenced by motivation and self-efficacy. This research aligns with the findings of Yang et al. (2023), where combining digital media and self-efficacy enhances student engagement in science learning. However, studies examining the interaction between these internal and external factors are limited, even though both are critical to science education. This study offers an opportunity to explore these factors more deeply and reveal how they influence science learning.

This research is increasingly vital as it can provide a deeper understanding of how appropriate learning media can stimulate student interest and attention, as well as what innovations can be tailored to the diverse characteristics of students. Additionally, this research has the potential to offer solutions to the challenges faced by teachers in designing more effective and engaging science education processes. This study aims to identify and analyse the factors influencing science learning in the discovery model at schools, focusing on developing innovative strategies to address the existing challenges.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

METHODOLOGY

Research Design

The research design employs a mixed-methods approach, integrating quantitative and qualitative methodologies to examine the relationships between variables while exploring the contextual dynamics in depth (Creswell & Creswell, 2018) concerning the factors influencing science learning. The quantitative approach tests the statistical relationships between variables, while the qualitative approach, through in-depth interviews with teachers, aims to understand classroom dynamics that cannot be statistically measured (Tashakkori & Teddlie, 2010). This design was chosen to provide a more comprehensive convergent validity regarding the factors affecting science education and how these factors interact with each other.

Population and Sample

The research population consists of eighth-grade students and teachers from junior high schools in the Special Region of Yogyakarta for the 2025 academic year, utilising the discovery model during the learning process. The selection of eighth-grade students is based on their age, approximately 13-14 years, which corresponds to early adolescence. This age represents a significant period of psychological and social development, making it a key focus for research on behavioral changes, cognitive growth, and social development, which are closely tied to science education. The sampling technique employed is census sampling, resulting in a sample of 179 students and teachers, as shown in Table 1. This study uses source triangulation, involving data from students (quantitative) and data from teachers (qualitative), to provide a more holistic perspective on the research issue. Findings from both sources will complement each other, enhancing the research outcomes' validity.

Table 1. Sample Demographic

Item	Response	Frequency	Percentage (%)
Class Type (code)	VIII-A	31	17,3
	VIII-B	30	16,8
	VIII-C	31	17,3
	VIII-D	31	17,3
	VIII-E	30	16,8
	VIII-F	26	14,5
Respondents' Gender	Male	85	47,5
	Female	94	52,5
Lerning style	Visual	38	21,2
	Auditory	53	29,6
	Kinesthetic	88	49,2
Information Acces	Very Available	26	14,5
	Available	142	79,3
	Not Available	11	6,1
	Very Not Available	0	0

Instrument

The primary instrument for collecting quantitative data is a questionnaire consisting of 4 scales designed to measure the variables under investigation. The questionnaire employs a 4-point Likert scale for each item, facilitating data collection and statistical analysis. The instrument for collecting qualitative data is an interview guide for interviewing teachers. This interview guide will include open-ended questions to explore teachers' challenges, constraints, and needs in teaching science.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Data analysis

Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis was chosen for this study to examine the complex relationships between exogenous, mediating, and endogenous variables (Hair et al., 2019). PLS-SEM is well-suited for this research because it can handle relatively small sample sizes (Hair et al., 2017), measure both direct and indirect effects (Hair et al., 2011), and is compatible with exploratory models (Henseler, 2018). This study involves several variables derived from teacher interviews and developed into factors influencing science learning when teachers apply the discovery learning model. These variables are used to assess student perceptions as the subjects of science learning.

Exogenous Variables (X)
X1: Self-efficacy
X2: Motivation
X3: Epistemological Beliefs
X4: Technology Readiness
X5: Curiosity

Mediating Variable (Z)
Z: Engagement in Learning

Endogenous Variables (Y)
Y1: Perception of Learning Media effectiveness
Y2: Perception of Learning Model’s 's effectiveness

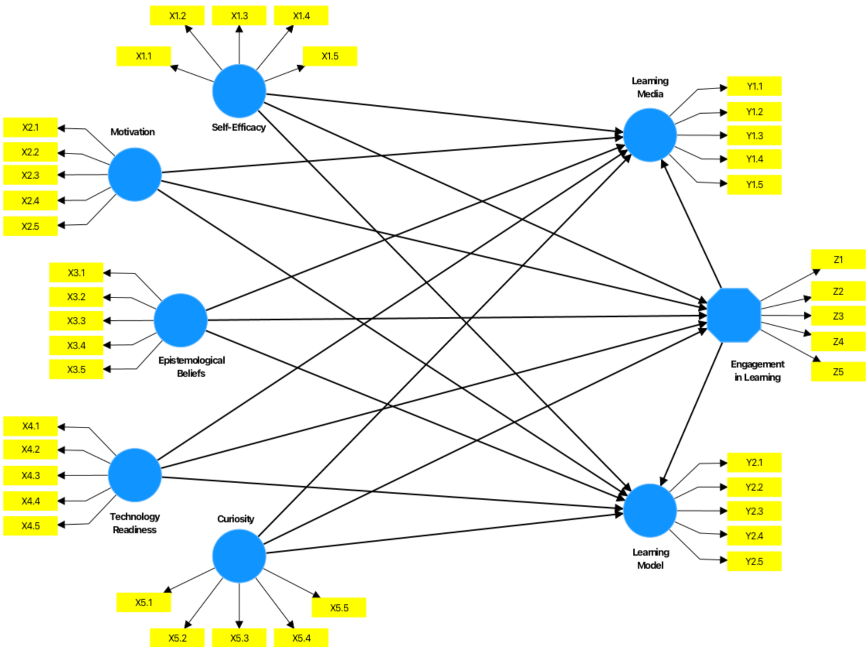


Figure 1. Research Framework

The first step in PLS-SEM analysis is to conduct validity and reliability tests of the instruments. The analysis process begins with testing the validity and reliability of the instruments. Convergent validity is assessed through Confirmatory Factor Analysis (CFA) with the criteria of outer loading > 0.7 and Average Variance Extracted (AVE) > 0.5 (Fornell & Larcker, 1981), while reliability is measured using Composite Reliability (CR) > 0.7 and Cronbach’s alpha > 0.7 (Nunnally, 1978). Model fit testing is not a requirement for PLS-SEM, as PLS-SEM emphasizes criteria such as construct validity and reliability, as well as predictive power, as the primary indicators of model

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

quality (Henseler et al., 2015). The next step is path analysis, where the path coefficients (β) and their significance are evaluated through bootstrapping with 5000 subsamples (Hair et al., 2017). Mediation effects are tested using Variance Accounted For (VAF), where values >20% indicate partial mediation and values >80% indicate complete mediation (Hair et al., 2017). The model's predictive power is evaluated using R^2 (Chin, 1998) and Q^2 predictive relevance (Geisser, 1975), with effect size interpreted according to Cohen's criteria (Cohen, 2013).

Qualitative data obtained through in-depth teacher interviews are analyzed using a thematic approach (Braun & Clarke, 2006). The first step in this analysis is transcribing the interviews to make the data easier to interpret. Then, the transcribed data are coded by labeling the data units relevant to the studied topics. After coding, the researcher identifies the main themes from the interviews. These themes are then further analyzed to understand how each theme contributes to a deeper understanding of the challenges faced in science education.

RESULTS AND DISCUSSION

Construct Validity and Reliability

The analysis results in Table 2 present various indicators related to the construct validity and reliability within the research model. Each construct is tested through multiple measurement items, which are evaluated based on loadings, weights, and several other statistical indices such as Composite Reliability (CR), Cronbach's Alpha (CA), Average Variance Extracted (AVE), and Variance Inflation Factor (VIF).

Table 2. Construct Validity and Reliability

Constructs	Items	Loadings	Weights	CA	CR	AVE	VIF
Self-Efficacy (SE)	X1.1	0.538	0.242				1.136
	X1.2	0.630	0.324				1.184
	X1.3	0.503	0.182	0.630	0.766	0.402	1.178
	X1.4	0.739	0.417				1.235
	X1.5	0.723	0.367				1.298
Motivation (Mtv)	X2.1	0.686	0.315				1.349
	X2.2	0.598	0.223				1.268
	X2.3	0.683	0.277	0.719	0.816	0.471	1.355
	X2.4	0.701	0.337				1.317
	X2.5	0.754	0.298				1.486
Epistemological Beliefs (EB)	X3.1	0.668	0.266				1.336
	X3.2	0.702	0.336				1.282
	X3.3	0.709	0.295	0.718	0.815	0.470	1.383
	X3.4	0.761	0.343				1.463
	X3.5	0.573	0.202				1.251
Technology Readiness (TR)	X4.1	0.766	0.281				1.603
	X4.2	0.767	0.271				1.608
	X4.3	0.646	0.238	0.791	0.857	0.546	1.307
	X4.4	0.773	0.306				1.555
	X4.5	0.737	0.253				1.550
Curiosity (Csy)	X5.1	0.811	0.292				1.850
	X5.2	0.751	0.305				1.482
	X5.3	0.697	0.192	0.807	0.866	0.564	1.558
	X5.4	0.754	0.254				1.611
	X5.5	0.738	0.284				1.492
	Y1.1	0.666	0.326	0.691	0.800	0.451	1.237

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Constructs	Items	Loadings	Weights	CA	CR	AVE	VIF
Leaning Media (LMe)	Y1.2	0.715	0.304				1.358
	Y1.3	0.794	0.365				1.539
	Y1.4	0.670	0.291				1.333
	Y1.5	0.471	0.171				1.130
Learning Model (LMo)	Y2.1	0.673	0.277				1.376
	Y2.2	0.598	0.224				1.386
	Y2.3	0.692	0.329	0.719	0.816	0.471	1.354
	Y2.4	0.725	0.307				1.398
	Y2.5	0.736	0.312				1.613
Engagement in Learning (EiL)	Z1	0.600	0.220				1.271
	Z2	0.697	0.304				1.354
	Z3	0.617	0.315	0.676	0.793	0.435	1.259
	Z4	0.743	0.309				1.519
	Z5	0.629	0.369				1.209

Indicators such as X1.1, X2.1, X3.1, etc., act as observation variables used to measure and validate larger constructs in PLS-SEM. The relationship between these indicators and constructs is crucial to ensure that the model built accurately reflects the relationships present in the research data. Several indicator values are slightly lower than the generally accepted standards and, such as loadings below 0.70 and Cronbach's Alpha (CA) slightly below the ideal value of 0.70. However, in the context of exploratory research, these values be interpreted differently, and such values can be accepted with the justification that the goal of the research is to explore and understand phenomena in greater depth. This result is particularly true when the constructs or instruments are in the development stage. Exploratory research offers the flexibility to accept these values, provided there is strong justification regarding the relevance and contribution of the items in measuring the intended construct.

The Self-Efficacy construct shows item loadings that vary, with the lowest value being 0.503 for item X1.3 and the highest value being 0.739 for item X1.4. Although some items have loadings lower than 0.70, such as X1.1 (0.538) and X1.3 (0.503), this can be accepted in the context of exploratory research. The Cronbach's Alpha (CA) value for this construct is 0.630, slightly lower than the ideal 0.70, but it is acceptable for exploratory research. The Composite Reliability (CR) value of 0.766 indicates good reliability, suggesting that this instrument is reasonably consistent in measuring the Self-Efficacy construct. However, the Average Variance Extracted (AVE) value of 0.402 suggests that the indicators in this construct explain less than 50% of the variance in the construct, suggesting the potential for improving measurement in this construct in future studies. The Variance Inflation Factor (VIF) value of 1.136 indicates no significant multicollinearity among the items.

The Motivation construct shows loading values ranging from 0.598 for item X2.1 to 0.754 for item X2.5, demonstrating a good contribution from each item to the construct. The Cronbach's Alpha (CA) value of 0.719 indicates good reliability, exceeding the threshold of 0.70, which means the construct has a sufficiently strong internal consistency. The Composite Reliability (CR) value of 0.816 affirms that the Motivation construct is highly reliable. Although the Average Variance Extracted (AVE) value is 0.471, slightly below 0.50, it falls within the tolerance limits for exploratory research. This construct's Variance Inflation Factor (VIF) is 1.349, showing no significant multicollinearity among the items.

The Epistemological Beliefs construct shows item loadings ranging from 0.573 for item X3.5 to 0.761 for item X3.4, with several items having loadings slightly below 0.70, such as X3.5 (0.573). However, this is acceptable in the context of exploratory research. The Cronbach's Alpha (CA) value of 0.718 indicates reasonably good reliability, exceeding 0.70. The Composite Reliability (CR) value of 0.815 indicates that this construct has good internal consistency. However, the Average Variance Extracted (AVE) value of 0.470 is slightly below 0.50, indicating that the indicators in this construct do not fully explain the variance within the construct. Nevertheless, this can be accepted in

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

exploratory research. The Variance Inflation Factor (VIF) value 1.336 also indicates no significant multicollinearity.

The Technology Readiness construct shows excellent loadings ranging from 0.646 to 0.767, indicating strong contributions from all items in this construct. The Cronbach's Alpha (CA) value for this construct is 0.791, indicating excellent reliability, exceeding the 0.70 threshold. The Composite Reliability (CR) value of 0.857 suggests that this construct has high internal consistency. The Average Variance Extracted (AVE) value of 0.546 indicates that the construct explains more than 50% of the variance in its indicators, suggesting that it has excellent convergent validity. The Variance Inflation Factor (VIF) of 1.603 indicates no significant multicollinearity in this construct.

The Curiosity construct shows item loadings ranging from 0.697 to 0.811, with item X5.1 having the highest loading value. The Cronbach's Alpha (CA) of 0.807 indicates excellent reliability, greater than 0.70, meaning this construct has very high internal consistency. The Composite Reliability (CR) value of 0.866 also shows excellent reliability, proving that this instrument is highly consistent in measuring the Curiosity construct. The Average Variance Extracted (AVE) value of 0.564 shows that this construct is very good at explaining the variance in its indicators, indicating strong validity. The Variance Inflation Factor (VIF) value of 1.850 indicates no significant multicollinearity in this construct.

The Learning Media construct shows loadings ranging from 0.471 to 0.794, with item Y1.5 having the lowest loading at 0.471, indicating that this indicator is less intense in measuring the Learning Media construct. The Cronbach's Alpha (CA) value of 0.691 indicates reliability slightly below 0.70, but it is still acceptable for exploratory research. The Composite Reliability (CR) of 0.800 indicates fairly good consistency, although some items show lower contributions. The Average Variance Extracted (AVE) value of 0.451 shows that this construct is not optimal in explaining the variance of its indicators, which should be addressed in future research. The Variance Inflation Factor (VIF) of 1.237 indicates no significant multicollinearity.

The Learning Model construct shows loadings ranging from 0.598 to 0.736, with item Y2.2 having the lowest loading (0.598). The Cronbach's Alpha (CA) value of 0.719 indicates good reliability, exceeding 0.70, indicating that this construct has sufficiently strong internal consistency. The Composite Reliability (CR) of 0.816 shows that this construct is reliable in measuring the intended variable. The Average Variance Extracted (AVE) value of 0.471 indicates that the indicators in this construct do not explain more than 50% of the variance, which warrant attention in future studies. The Variance Inflation Factor (VIF) of 1.613 indicates no significant multicollinearity.

The Engagement in Learning construct shows loadings ranging from 0.600 to 0.743, with item Z1 having the lowest loading (0.600) and Z4 having the highest (0.743). The Cronbach's Alpha (CA) of 0.676 is slightly below 0.70 but is acceptable in exploratory research. The Composite Reliability (CR) of 0.793 indicates reasonably good internal consistency. The Average Variance Extracted (AVE) of 0.435 suggests that the indicators in this construct are less effective in explaining the variance, which requires attention. The Variance Inflation Factor (VIF) of 1.271 indicates no significant multicollinearity.

Most of the constructs in this study show promising results in terms of reliability and validity, with Cronbach's Alpha and Composite Reliability values generally above 0.70 and Average Variance Extracted (AVE) values indicating adequate convergent validity for most constructs. Some constructs, such as Learning Media, Self-Efficacy, and Engagement in Learning, show lower AVE values and loadings, suggesting a need for improvement in measurement in these constructs. However, the low VIF values across all constructs indicate no significant multicollinearity issues, and these results are acceptable in the context of exploratory research.

In addition to construct validity and reliability presented in Table 2, the Heterotrait-Monotrait Ratio (HTMT) analysis serves as a crucial tool for assessing discriminant validity within Structural Equation Modeling (SEM). Discriminant validity ensures that each construct in the model is empirically distinct from others, indicating the absence of excessive overlap or overly strong correlations between constructs. HTMT offers a more robust measure of discriminant validity compared to traditional approaches, such as the Fornell-Larcker criterion, as it evaluates explicitly

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

the ratio between heterotrait correlations (i.e., correlations between different constructs) and monotrait correlations (i.e., correlations within the same construct). An HTMT value is deemed acceptable if it falls below a certain threshold, generally 0.85 or, in some cases, 0.90, indicating sufficient discriminant validity and suggesting that the constructs are distinct and not excessively interrelated. Conversely, HTMT values exceeding these thresholds signal construct overlap, thereby potentially compromising the model's validity.

Table 3. Heterotrait-Monotrait Ratio (HTMT)

	Csy	EiL	EB	LMe	LMo	Mtv	SE
Csy							
EiL	0.766						
EB	0.700	0.642					
LMe	0.715	0.640	0.635				
LMo	0.787	0.773	0.555	0.838			
Mtv	0.814	0.708	0.771	0.695	0.751		
SE	0.726	0.756	0.714	0.602	0.631	0.848	
TR	0.641	0.716	0.622	0.839	0.523	0.568	0.619

Note: Self-Efficacy (SE); Motivation (Mtv); Epistemological Beliefs (EB); Technology Readiness (TR); Curiosity (Csy); Leaning Media (LMe); Learning Model (LMo); Engagement in Learning (EiL)

Table 3 presents the HTMT calculation results used to evaluate discriminant validity within the SEM framework. Most HTMT values across constructs are below 0.85, indicating strong evidence of discriminant validity in the model. For instance, the HTMT value between Curiosity and Engagement in Learning is 0.766, which is below the 0.85 benchmark, suggesting these two constructs are empirically distinct and not overly redundant. Other pairings, such as those between Motivation and Self-Efficacy (0.848) and Learning Model (0.751), show relatively high correlations but remain within acceptable bounds, thus supporting their conceptual independence despite moderate associations. A few HTMT values, such as that between Technology Readiness and Learning Model (0.839), approach the threshold, potentially indicating some conceptual overlap. Nevertheless, the majority of HTMT values, such as those between Learning Media and Epistemological Beliefs (0.635), affirm adequate differentiation among the constructs. Overall, the HTMT results support the discriminant validity of the constructs employed, reinforcing their suitability for further analysis within the SEM framework.

Model fit is a crucial step in statistical analysis used to assess the degree to which an estimated model aligns with the available data. The evaluation of model fit typically involves comparing the estimated model with a more complex or "saturated model," which encompasses all possible relationships among the variables. Several indicators are utilized to gauge the adequacy of the model fit (table 4), such as SRMR (Standardized Root Mean Square Residual), d_ULS, d_G, Chi-square, and NFI (Normed Fit Index).

Table 4. Model Fit

	Saturated model	Estimated model
SRMR	0.086	0.087
d_ULS	6.057	6.244
d_G	1.616	1.644
Chi-square	1502.229	1520.068
NFI	0.533	0.528

Based on the results in Table 4 derived from the model fit table, the model fit analysis between the saturated model and the estimated model reveals a satisfactory level of correspondence, despite some minor discrepancies in specific indicators. The SRMR values for both models are 0.086 for the saturated model and 0.087 for the estimated model, indicating an almost negligible difference between the two, both of which fall within the acceptable range (an SRMR value below 0.08 is

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

typically considered indicative of a good fit). This result suggests that the estimated model effectively represents the interrelationships among the variables, closely approximating the more intricate saturated model.

Subsequently, the d_ULS (Unweighted Least Squares) indicator for the saturated model is 6.057, while for the estimated model it is 6.244, revealing a negligible difference and implying that both models exhibit similar residual errors, regardless of the weights of the variables. The d_G indicator, serving as an alternative to d_ULS by accounting for the distribution of the variables, also yields comparable results: 1.616 for the saturated model and 1.644 for the estimated model, both of which suggest that the estimated model exhibits an excellent fit.

The Chi-square test, which assesses how well the estimated model aligns with the observed data, provides a value of 1502.229 for the saturated model and 1520.068 for the estimated model. Despite the slight increase in the Chi-square value for the estimated model, this difference is marginal and does not indicate any significant issues with model fit. Finally, the NFI value for the saturated model is 0.533, while for the estimated model, it is 0.528, reflecting a slight decrease in the estimated model. However, both values remain within an acceptable range. Ideally, the NFI should be closer to 1. Overall, these results suggest that the estimated model demonstrates an excellent fit to the data, with minimal discrepancies when compared to the saturated model, implying that the estimated model can be deemed a sufficiently accurate representation of the relationships among the variables.

Factors Affecting Science Learning

The path analysis results test the direct relationships between the variables involved in this research model. This path analysis aims to identify each variable's direct effects on the others and determine the significance of these relationships. The path analysis values indicate the strength of the relationships between the variables, while the p-value assesses the statistical significance of these relationships (Figure 2).

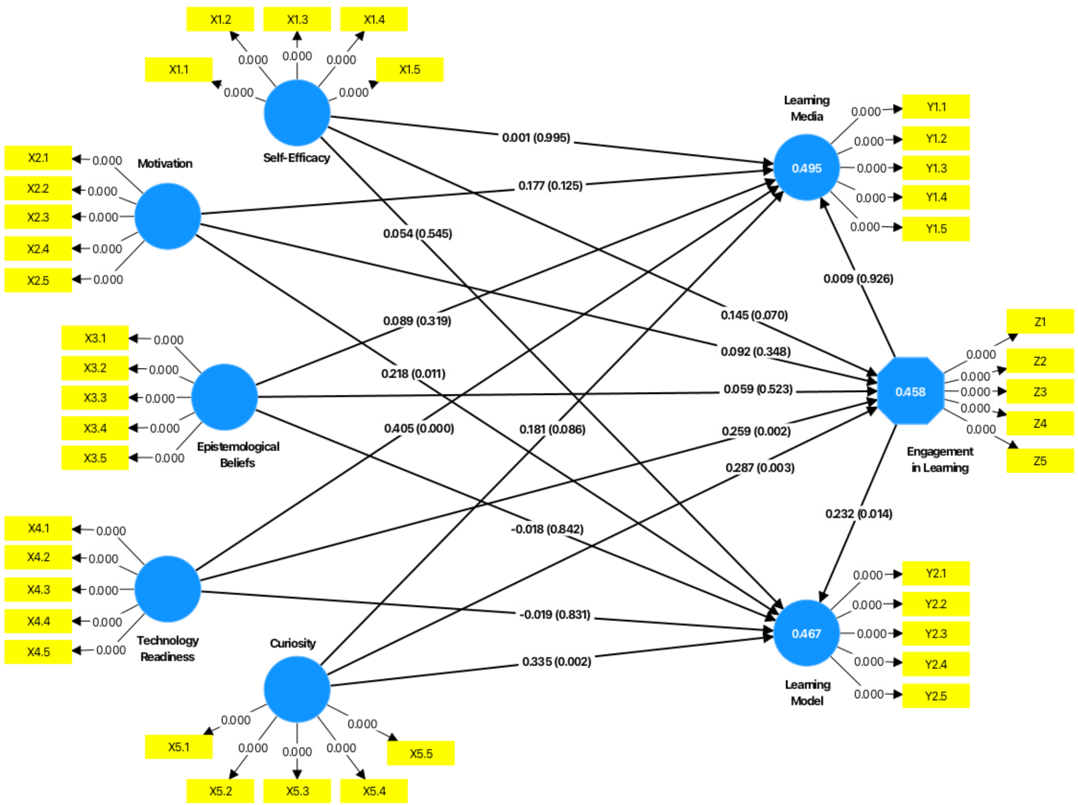


Figure 2. Testing Hypothesis

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Table 5. Path Coefficient

	Sample mean	Standard deviation	T statistics
Csy -> EiL	0.287	0.095	3.022
Csy -> LMe	0.184	0.105	1.719
Csy -> LMo	0.337	0.107	3.135
EiL-> LMe	0.009	0.094	0.093
EiL-> LMo	0.228	0.094	2.463
EB-> EiL	0.061	0.092	0.639
EB-> LMe	0.093	0.090	0.996
EB-> LMo	-0.017	0.089	0.200
Mtv -> EiL	0.091	0.098	0.939
Mtv -> LMe	0.173	0.115	1.536
Mtv -> LMo	0.212	0.086	2.536
SE-> EiL	0.154	0.080	1.815
SE-> LMe	0.001	0.082	0.006
SE-> LMo	0.062	0.090	0.606
TR-> EiL	0.256	0.084	3.084
TR-> LMe	0.412	0.090	4.497
TR-> LMo	-0.014	0.089	0.214

The relationship between Curiosity and Engagement in Learning shows a significant result, with a p-value of 0.003, much smaller than the 0.05 threshold. The T-statistic value of 3.022 also indicates a strong and significant relationship. This result suggests that curiosity has a strong positive influence on engagement in learning. Therefore, it can be concluded that the higher an individual's curiosity, the greater the likelihood that students will engage in the learning process. This finding aligns with the Self-Determination Theory (SDT), which states that curiosity, as intrinsic motivation, encourages active engagement (Ryan & Deci, 2020). Empirical studies by Litman (2005) also confirm that students with high curiosity tend to be more exploratory in their learning.

The relationship between Curiosity and Learning Media shows a non-significant result (p-value = 0.086). Although these two variables have a positive influence, the p-value greater than 0.05 suggests that the effect is not strong enough to be considered significant. This result indicates that while curiosity influence the use of learning media, its impact is not substantial within the context of this study.

The relationship between Curiosity and Learning Model shows a significant positive effect (p-value = 0.002, T-statistics = 3.135). The very small p-value and high T-statistics confirm this relationship is statistically significant. This result means that individuals with high curiosity tend to prefer or become more engaged with specific learning models, emphasizing the importance of curiosity in shaping one's approach to learning. This finding is supported by von Stumm et al. (2011), who found that inquisitive individuals are likelier to choose inquiry-based learning methods.

The relationship between Engagement in Learning and Learning Media shows no significant result (p-value = 0.926), indicating no direct and strong relationship between engagement in learning and the use of learning media in this study. Similar results were found for the relationships between Epistemological Beliefs and Engagement in Learning (p-value = 0.523) and Learning Media (p-value = 0.319), showing no significant influence. In other words, epistemological beliefs, or one's views about knowledge, do not have a substantial enough impact on student engagement in learning or the use of learning media.

Additionally, the relationship between Epistemological Beliefs and Learning Model is not significant (p-value = 0.842), suggesting that one's view on how knowledge should be learned does not directly influence the learning model chosen by students. This finding implies that epistemological beliefs not be a significant factor in selecting or accepting a particular learning model. This result contrasts with previous studies (Hofer, 2000), suggesting that epistemological

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

beliefs affect learning approaches. The insignificance of this relationship also be due to the specific context of science learning in Indonesia, which is more structured (Tsai et al., 2011), and the less sensitive measurement of the construct (Schommer-Aikins, 2004).

However, the relationship between Motivation and Learning Model shows a significant result (p-value = 0.011, T-statistics = 2.536), indicating that motivation significantly influences the choice or acceptance of learning models. This result is consistent with the Expectancy-Value Theory (Eccles & Wigfield, 2002), which suggests that motivation affects the selection of learning strategies. However, the relationship between Motivation and Engagement in Learning (p-value = 0.348) and Learning Media (p-value = 0.125) is insignificant, indicating that while motivation plays a crucial role in selecting learning models, it does not significantly influence engagement levels or the use of learning media. This result is likely because extrinsic motivation is insufficient to drive deep engagement (Deci et al., 1999).

The relationship between Self-Efficacy and Engagement in Learning shows a p-value of 0.070, slightly greater than 0.05. This result supports Bandura's theory (Bandura, 1997) that self-efficacy plays a role in learning perseverance, but other factors moderate its effects. Although there is a positive influence between Self-Efficacy and Engagement in Learning, the effect is only marginally significant and needs further exploration in future research. On the other hand, the relationships between Self-Efficacy and Learning Media (p-value = 0.995) and Learning Model (p-value = 0.545) are insignificant, indicating that self-confidence does not directly influence the use of learning media or the chosen learning model.

Meanwhile, Technology Readiness shows significant results in its relationship with Engagement in Learning (p-value = 0.002, T-statistics = 3.084) and Learning Media (p-value = 0.000, T-statistics = 4.497). This result indicates that technology readiness significantly influences engagement in learning and the use of learning media. These results are consistent with studies by Parasuraman (2000) and Dwivedi et al. (2019) regarding the role of technology in enhancing learning participation. High technology readiness tends to encourage individuals to engage more in learning and prefer or use the available learning media. However, the relationship between Technology Readiness and Learning Model is insignificant (p-value = 0.831), suggesting that technology readiness does not directly influence the learning model choice.

The path analysis results show that variables such as Curiosity, Motivation, and Technology Readiness significantly affect several aspects of learning, particularly in the Learning Model and Learning Media. However, other relationships, such as those between Epistemological Beliefs, Self-Efficacy, and Learning Media, do not show significant effects, suggesting that these factors not play a strong role in determining the selection or use of learning models and media. These findings provide important insights into the factors influencing the learning process and can be used to design more effective learning strategies based on the variables that have been proven significant.

The findings of this study are supported by interviews with teachers, which provide a deeper understanding of the challenges faced in science education, particularly regarding learning models, learning media, and how student characteristics affect the learning process. One key finding from the interviews is that the implemented learning model strongly influences students' needs. However, teachers face significant difficulties finding the right media or resources to stimulate students before the learning process begins, especially for more complex and abstract materials.

The Relationship Between Learning Models, Media Limitations, and Student Needs

The analysis process begins with transcribing the interviews to make the data easier to analyze, followed by coding to assign labels to data units relevant to the studied topics. After coding, the researcher identifies the main themes that emerge from the interviews, which are then further analyzed to understand how each theme provides deeper insights into the challenges faced in science education, particularly when implementing the discovery learning model. Table 6 presents the key findings obtained from the thematic analysis of the teacher interviews.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Table 6. Theme Result

Theme	Description	Key Points
Learning Model: Discovery Learning	The discovery learning model increases student engagement in problem-based and discovery-based learning.	Student Engagement, Problem Solving, Discovery-Based Approach
Limitations of Learning Media	Limitations in media that can stimulate students before learning begins, as well as a lack of suitable materials on common platforms.	Material Access Limitations, Media Quality Limitations, Language Issues
Need for Appropriate Learning Media	Interactive and engaging media that can stimulate students' critical thinking is required, especially for complex material.	Student Engagement with Interactive Media, Visualization of Complex Material, Resource Limitations
Development of Learning Media	The development of more comprehensive learning media that aligns with the characteristics of learning models, such as discovery learning.	Innovation in Media Development, Teacher Training, Collaboration with External Parties
Collaboration and Resources	Collaboration between schools and external parties to obtain relevant and affordable student resources.	Enhancing Collaboration, Affordable Access for All Students
Challenges in Implementing Discovery Learning	The main challenge is the lack of suitable media to effectively support the implementation of the discovery learning model.	Media Limitations in Model Implementation

One of the key findings from the interviews is that the learning model applied in the classroom significantly influences how students learn, and therefore, students' needs vary according to the approach used. Teachers often choose the discovery learning model to teach science content. This model, which emphasizes a problem-based and discovery approach, is highly effective in increasing student engagement. Students do not merely passively receive information; they are allowed to discover concepts through practical activities, experiments, and discussions. Discovery learning enables students to actively engage in the learning process by identifying real-world problems around them and solving them independently. The finding that discovery learning enhances student participation is consistent with Bruner (1961) research, which emphasizes the role of active learning in knowledge construction. This model allows students to develop understanding through self-directed exploration (HMELO-SILVER et al., 2007).

Although this model has proven effective in increasing student engagement, a significant challenge teachers face is the difficulty in providing learning media that can stimulate students before learning begins. Teachers' difficulty in providing initial stimulation supports the criticism by Kirschner et al. (2006) that discovery learning requires adequate scaffolding, especially for complex content. The initial stimulus provided to students is critical in the discovery learning model because it can enhance students' curiosity and prepare them to engage in learning more actively. However, not all content needed for discovery learning can be easily found on common platforms like YouTube. Many materials are unavailable or not processed in a way that stimulates the discussions or in-depth exploration required in discovery learning.

The interview results also show that although some learning media, such as the PhET application for simulations, have been used, these media are not sufficient to address various learning needs, especially for more abstract or complex content. For instance, in science education, some abstract concepts, such as theories in physics or chemistry, require more concrete media to help students

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

visualize these concepts. While PhET provides visual simulations for certain concepts, these media often fail to cover all the aspects needed to optimize students' understanding, especially for more complex concepts or material that cannot be easily simulated using available tools. The limitations of PhET simulations in visualizing abstract concepts align with er (2009)findings that the effectiveness of multimedia depends on its alignment with students' cognitive levels.

Additionally, limitations in the language used in learning media pose a separate issue. Some learning media use technical or mathematical language that be difficult for students to understand without additional explanation or teaching. When students encounter complex content that requires basic mathematical knowledge or specialized skills, they often struggle to understand the message conveyed through the media. The issue of understanding technical language reinforces Sweller (2010) cognitive load theory, where overly complex material can overload students' working memory (Firdaus, Amelia, et al., 2025). Therefore, while various resources are available on the internet, not all are adequate to support discovery learning, requiring richer stimuli to trigger critical thinking and in-depth discussions. Media is needed based on the cognitive theory of multimedia learning (CTML), which integrates text, visuals, and interactivity (er, 2009).

Media Needs Suitable for Learning Models

Teachers stated that the learning media needed must be able to provide initial stimuli to students, so they are better prepared to engage in discovery-based learning activities and discussions. However, the existing media are often limited and do not always match the learning model's characteristics. Students need more interactive and engaging media to introduce them to real-world problems relevant to the studied material and facilitate deep exploration. This result is significant for discovery learning, which requires stimuli that allow students to formulate problems, engage in discussions, and discover solutions independently. er (2004) research on prior knowledge activation in learning supports the finding that discovery learning requires strong initial stimuli. Teachers need media that can trigger students' curiosity (Kang et al., 2009), present contextual problems (Hmelo-Silver, 2004), and facilitate scaffolding (Quintana et al., 2004).

Teachers revealed that videos or other media sources that can stimulate students' understanding of more complex content are greatly needed, but the available resources often do not cover all the aspects needed to deliver the material in depth. Teachers also mentioned that visualization media for highly technical content or concepts requiring complex conceptual understanding are essential. Therefore, developing more innovative learning media, aligned with the characteristics of students and the learning models, is crucial to address these gaps. The limitations of visualization media for abstract concepts align with Kozma (2003) findings on the importance of multimodal representation, Ainsworth (2006) work on the functions of multiple representations, and de Jong et al. (2014) regarding inquiry-based simulations.

Based on these findings, teachers suggest that to improve the quality of science learning, more comprehensive learning media must be developed that align with the applied learning model, such as discovery learning. Developing innovative media that can provide more effective stimuli is crucial, especially when teaching abstract or complex content. Teachers also expect further training on developing or adapting learning media to meet specific students' needs, particularly in terms of visualizing material that is difficult to comprehend through theory or verbal explanations alone. Teachers' suggestions about the need for innovative media are supported by Plass et al. (2020) principles of multimedia learning and Chen et al. (2019) on adaptive learning technologies.

Moreover, it is important to enhance collaboration between schools and external parties, such as educational communities or offices, to obtain more relevant and suitable resources for learning needs. Teachers hope that the existing learning media can be more interactive, practical, affordable, and sufficient for all student characteristics, so that all students, regardless of their learning style, can gain maximum benefit.

Although the discovery learning model has proven effective in increasing student engagement, providing the right learning media remains one of the main challenges teachers face. Students' learning needs greatly depend on the learning model used, but the learning process cannot proceed

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

optimally without appropriate media to stimulate students. Therefore, there is a need for the development of more relevant and innovative learning media, which can help students better understand the material, especially complex or abstract content, and support the implementation of more active, discovery-based learning models like discovery learning.

Exploring the Creation of Innovation

Based on the path analysis results and interviews, we can conclude that stimuli support the learning process, particularly in the discovery learning model. The path analysis results show that Curiosity significantly impacts Engagement in Learning and the Learning Model, indicating that students' curiosity plays a significant role in motivating their engagement in learning. However, to facilitate this process, teachers face a significant challenge in providing media to stimulate students before the learning begins. Therefore, developing effective stimulus media is essential to support the success of discovery learning.

One key finding from the interviews is that in discovery learning, the initial stimulus process is significant for sparking students' curiosity and preparing them to engage actively in learning. This stimulus motivates students and provides a context relevant to the material that will be studied. Therefore, effective stimuli will make it easier for students to formulate questions, identify problems, and find solutions in the discovery-based learning process.

However, although students' curiosity significantly impacts Engagement in Learning (p-value = 0.003), the primary challenge teachers face is difficulty finding or developing the right media to stimulate students before the learning begins, especially with abstract content. Therefore, the media developed should be able to provide relevant stimuli and spark students' curiosity so that they can become more deeply involved in this learning model.

One leading solution proposed is the development of stimulus media based on real-world problems that can be directly related to the content to be learned. The interview results indicate that the discovery learning model requires stimulus based on real-world problems because it allows students to discover and solve issues relevant to their lives. The use of documentary videos or real-world simulations presenting problems that students can study and solve is very effective in sparking students' curiosity.

For example, in science education, a video showing a natural phenomenon or a science experiment that triggers interesting questions could be used to provide the necessary stimulus. These videos should be presented challengingly, sparking curiosity, so students feel motivated to explore and discover the answers during the learning process. With real-world problem-based stimuli, students can connect learning to real life more easily and become more engaged in discovery learning activities.

The interview results also found that collaboration with external parties, such as educational app developers or educational communities, is crucial for enhancing the quality of stimulus media used in learning. This collaboration can include the provision of technology-based teaching materials that are more in line with the needs of the discovery learning model. For instance, collaboration with virtual simulation development companies or web-based educational platforms can produce richer and more engaging stimulus media.

Furthermore, collaboration between schools and other educational institutions can help provide more relevant and innovative resources (Firdaus, 2025), such as training courses for teachers on utilizing available stimulus media to support discovery-based learning models. With the help of technology and external resources, more varied and effective stimulus media can be developed to assist students in the learning process.

To support the success of the discovery learning model, it is vital to develop stimulus media that aligns with the characteristics of students and the material being taught. Based on the path analysis results and interviews, Curiosity and Technology Readiness play significant roles in increasing student engagement, and therefore, the media used to stimulate students must be able to spark students' curiosity and enhance active interaction in the learning process. Developing real-world problem-based media, interactive simulations, and collaboration with external parties are key to

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

creating effective media that supports discovery learning. Additionally, teacher training using relevant stimulus media is crucial in creating a more optimal learning experience.

To enhance science learning, particularly within the context of the Discovery Learning model, various aspects of innovation must be considered. Innovations in science education aim to create a more interactive, engaging, and practical learning experience. The following table 7 outlines several aspects of innovation required to support and strengthen the learning process, along with concrete steps that can be taken to achieve these goals.

Table 7. Innovation Framework

No	Aspect of Innovation	Required Innovation
1	Identification of Factors Affecting Science Learning in Discovery Model	Development of learning media that stimulates curiosity and supports student engagement.
2	Building Learning Media Relevant to Discovery Learning	Development of multimedia-based media and interactive simulations that ease the understanding of scientific material.
3	Utilization of Technology to Enhance Engagement in Learning	Integration of technology and educational platforms to support students' exploration of materials in a more contextual manner.
4	Enhancing Learning through Collaboration and External Resources	Collaboration with educational app developers and other educational institutions to create more innovative media.
5	Teacher Training and Competence Development	Organizing training for teachers on the use and adaptation of learning media and the latest technology.
6	Evaluation and Improvement of Learning Models and Media	Continuous evaluation and refinement of learning media and the models used.
7	Creation of Problem-Based Learning Media for Real-World Issues	Development of videos and simulations of real-world problems relevant to the material taught to trigger students' curiosity.

Research Limitation

Several indicators suggest values below the generally accepted standards, potentially impacting the construct validity of the measurement. In the Self-Efficacy (SE) construct, several items exhibit factor loadings lower than 0.70, such as item X1.3 (loading = 0.503). This value indicates that the item contributes less to the measured construct due to various factors. The item is less pertinent, thus failing to adequately represent the dimension intended in the construct. Additionally, the sample population used lacks consistent experiences or perceptions concerning the item. This weakens the item's relationship with the construct it is supposed to measure, thereby compromising the accuracy of the Self-Efficacy measurement.

Furthermore, Cronbach's Alpha (CA), which is slightly below 0.70 for certain constructs, such as Self-Efficacy (CA = 0.630), indicates lower internal reliability than the ideal threshold typically accepted. A lower CA can stem from inconsistencies in item responses or substantial variability between items measuring the same construct. For some constructs, items with divergent characteristics or focuses reduce the CA value, as these items are weakly correlated with one another.

The Average Variance Extracted (AVE) for several constructs also yields suboptimal results, falling well below the 0.50 threshold. This is due to the presence of items with low measurement quality, resulting in their inability to account for the majority of the variance within the construct. A low AVE can also be attributed to an insufficient or unrepresentative sample size, which hinders the optimal relationship between items and the construct. In this context, while these items be acceptable in exploratory research, the low AVE values suggest that the construct validity requires further enhancement.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Implication for Practice

Educators must design instructional strategies that stimulate students' curiosity, particularly during the initial stages of learning. The use of learning media that sparks curiosity, such as experimental videos or real-world problems relevant to the topic being studied, can enhance student engagement. Curriculum designers should consider integrating elements that foster students' inquisitiveness, such as incorporating problem-based tasks that encourage students to explore and discover scientific concepts. Policymakers should also allocate resources to support the development and dissemination of learning materials that stimulate curiosity and optimize students' learning experiences.

Moreover, this study reveals that interactive learning media, aligned with the discovery-based learning model, can significantly enhance students' comprehension. Teachers should be trained to select and utilize media that not only conveys information but also encourages students to engage in critical thinking and active participation in learning. Curriculum developers must create materials that not only align with learning objectives but also support the use of diverse media, such as simulation applications or interactive multimedia tools, which enable students to grasp complex and abstract scientific concepts more effectively. Policymakers should ensure that the curriculum accommodates technological advancements that can enrich students' learning experiences.

Teacher training also plays a crucial role in the successful implementation of the research findings. Educators must be equipped with the skills to utilize technology-based learning media and effectively integrate them into their everyday instructional practices. Teacher training curricula should include the use of technology and the development of media suited to the characteristics of students and the needs of discovery-based learning. Curriculum designers must ensure that teacher training programs facilitate the development of practical skills related to the effective use of technology in education. Meanwhile, policymakers need to support continuous training programs to enable teachers to optimize the use of these tools in the learning process.

CONCLUSION AND LIMITATIONS

Conclusion

This study reveals that various factors significantly influence science learning, particularly in the context of the discovery learning model. Curiosity has a substantial positive effect on student engagement and the choice of learning models, emphasizing the importance of intrinsic motivation in enhancing the learning experience. Technology readiness is another critical factor, showing a significant impact on engagement and the use of learning media, reinforcing the role of technology in facilitating active participation in the learning process. Motivation also plays a key role in selecting learning models, but its influence on engagement and media use is less pronounced. Conversely, factors like epistemological beliefs and self-efficacy showed minimal direct effects on engagement or the choice of learning media, suggesting that they not be as influential in the context of science learning in this study. Additionally, while discovery learning is a practical approach, the challenge remains in providing suitable media that can stimulate curiosity and engagement, especially for complex and abstract concepts.

The findings are further supported by interviews with teachers, which underscore the critical need for effective learning media that can spark students' curiosity and enhance their engagement. Teachers face significant challenges in providing the necessary stimuli before learning begins, particularly when dealing with abstract content. Therefore, there is a pressing need for innovative media that aligns with the discovery learning model, providing real-world problem-based stimuli to facilitate deep exploration and active learning.

Limitations

Despite the valuable insights gained from this study, several limitations should be acknowledged. Firstly, the sample size and context, which are specific to certain schools and regions, limit the generalizability of the findings to other educational settings. The study's focus on specific variables such as curiosity, motivation, and technology readiness overlook other potential factors influencing

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

learning outcomes, such as social influences or cultural contexts. Furthermore, the study primarily relied on self-reported data from both students and teachers, which be subject to bias and inaccuracies. Another limitation is the lack of longitudinal data, as the study only provides a snapshot of the current situation without considering how the factors influencing learning evolve. Lastly, while the study highlighted the challenges teachers face in finding suitable media for discovery learning, it did not extensively explore potential solutions for overcoming these challenges or evaluate the effectiveness of existing media in a more controlled environment. Further research could address these limitations by exploring a broader range of factors, employing a more diverse sample, and considering the long-term effects of various learning models and media on student engagement and learning outcomes.

REFERENCES

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction*, *16*(3), 183–198. https://doi.org/10.1016/j.learninstruc.2006.03.001

Bandura, A. (1997). *Self-efficacy: The exercise of control*. W. H. Freeman.

Barenthien, J. M., & Dunekacke, S. (2022). The implementation of early science education in preschool teachers' initial teacher education. A survey of teacher educators about their aims, practices and challenges in teaching science. *Journal of Early Childhood Teacher Education*, *43*(4), 600–618. https://doi.org/10.1080/10901027.2021.1962443

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching*, *43*(5), 485–499. https://doi.org/10.1002/tea.20131

Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review*, *32*, 21–32.

Chen, C.-H., Huang, C.-Y., & Chou, Y.-Y. (2019). Effects of augmented reality-based multidimensional concept maps on students' learning achievement, motivation and acceptance. *Universal Access in the Information Society*, *18*(2), 257–268. https://doi.org/10.1007/s10209-017-0595-z

Chin, W. W. (1998). *he partial least squares approach for structural equation modeling. In G. A. Marcoulides (Ed.), Modern methods for business research*. Lawrence Erlbaum Associates Publishers.

Cho, H. J., Zhao, K., Lee, C. R., Runshe, D., & Krousgrill, C. (2021). Active learning through flipped classroom in mechanical engineering: improving students' perception of learning and performance. *International Journal of STEM Education*, *8*(1), 46. https://doi.org/10.1186/s40594-021-00302-2

Cohen, J. (2013). *Statistical Power Analysis for the Behavioral Sciences*. Routledge. https://doi.org/10.4324/9780203771587

Creswell, J. W., & Creswell, J. D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage.

de Jong, T., Sotiriou, S., & Gillet, D. (2014). Innovations in STEM education: the Go-Lab federation of online labs. *Smart Learning Environments*, *1*(1), 3. https://doi.org/10.1186/s40561-014-0003-6

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin*, *125*(6), 627–668. https://doi.org/10.1037/0033-2909.125.6.627

Dwivedi, Y. K., Rana, N. P., Jeyaraj, A., Clement, M., & Williams, M. D. (2019). Re-examining the Unified Theory of Acceptance and Use of Technology (UTAUT): Towards a Revised Theoretical Model. *Information Systems Frontiers*, *21*(3), 719–734. https://doi.org/10.1007/s10796-017-9774-y

Eccles, J. S., & Wigfield, A. (2002). Motivational Beliefs, Values, and Goals. *Annual Review of Psychology*, *53*(1), 109–132. https://doi.org/10.1146/annurev.psych.53.100901.135153

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Firdaus, T. (2025). The Philosophical Construction of Educational Science in Relation to Posthumanism and Transhumanism in Artificial Intelligence. *Turkish Academic Research Review - Türk Akademik Araştırmalar Dergisi [TARR]*, *10*(1), 70–83. https://doi.org/10.30622/tarr.1610935

Firdaus, T., Amelia, A., Alifiyah, F. L. N., Nahdliyah, A. S., & Fausiyeh, F. (2025). Trends and Effects of Psychological and Cognitive Load in Education. *Journal of Education and Learning Reviews*, *2*(2), 97–128. https://doi.org/10.60027/jelr.2025.1084

Firdaus, T., Nurohman, S., Wilujeng, I., & Rahmawati, L. (2025). Exploring Motivational, Cognitive, and Instructional of Critical Thinking Disposition in Science Learning: The Mediating Role of Student Self-Regulation. *International Journal of Science Education and Teaching*, *4*(1), 12–25. https://doi.org/10.14456/ijset.2025.02

Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, *18*(1), 39. https://doi.org/10.2307/3151312

Geisser, S. (1975). The Predictive Sample Reuse Method with Applications. *Journal of the American Statistical Association*, *70*(350), 320. https://doi.org/10.2307/2285815

Haatainen, O., Turkka, J., & Aksela, M. (2021). Science Teachers' Perceptions and Self-Efficacy Beliefs Related to Integrated Science Education. *Education Sciences*, *11*(6), 272. https://doi.org/10.3390/educsci11060272

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)* (2nd Edition). Sage Publications Inc.

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a Silver Bullet. *Journal of Marketing Theory and Practice*, *19*(2), 139–152. https://doi.org/10.2753/MTP1069-6679190202

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review*, *31*(1), 2–24. https://doi.org/10.1108/EBR-11-2018-0203

Henseler, J. (2018). Partial least squares path modeling: Quo vadis? *Quality & Quantity*, *52*(1), 1–8. https://doi.org/10.1007/s11135-018-0689-6

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, *43*(1), 115–135. https://doi.org/10.1007/s11747-014-0403-8

Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, *16*(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

HMELO-SILVER, C. E., DUNCAN, R. G., & CHINN, C. A. (2007). Scaffolding and Achievement in Problem-Based and Inquiry Learning: A Response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, *42*(2), 99–107. https://doi.org/10.1080/00461520701263368

Hofer, B. K. (2000). Dimensionality and Disciplinary Differences in Personal Epistemology. *Contemporary Educational Psychology*, *25*(4), 378–405. https://doi.org/10.1006/ceps.1999.1026

Jansen, M., Schroeders, U., & Lüdtke, O. (2014). Academic self-concept in science: Multidimensionality, relations to achievement measures, and gender differences. *Learning and Individual Differences*, *30*, 11–21. https://doi.org/10.1016/j.lindif.2013.12.003

Kang, M. J., Hsu, M., Krajbich, I. M., Loewenstein, G., McClure, S. M., Wang, J. T., & Camerer, C. F. (2009). The Wick in the Candle of Learning. *Psychological Science*, *20*(8), 963–973. https://doi.org/10.1111/j.1467-9280.2009.02402.x

Kaushik, M. K., & Agrawal, D. (2021). Influence of technology readiness in adoption of e-learning. *International Journal of Educational Management*, *35*(2), 483–495. https://doi.org/10.1108/IJEM-04-2020-0216

Kibga, E. S., Gakuba, E., & Sentongo, J. (2021). Developing Students' Curiosity Through Chemistry Hands-on Activities: A Case of Selected Community Secondary Schools in Dar es Salaam,

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Tanzania. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(5), em1962. https://doi.org/10.29333/ejmste/10856

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist*, *41*(2), 75–86. https://doi.org/10.1207/s15326985ep4102_1

Kozma, R. (n.d.). *Technology, innovation and educational change: A global perspective*. Eugene.

Levin, T., & Wadmany, R. (2005). Changes in educational beliefs and classroom practices of teachers and students in rich technology-based classrooms[1]. *Technology, Pedagogy and Education*, *14*(3), 281–307. https://doi.org/10.1080/14759390500200208

Lin, T.-J. (2021). Multi-dimensional explorations into the relationships between high school students' science learning self-efficacy and engagement. *International Journal of Science Education*, *43*(8), 1193–1207. https://doi.org/10.1080/09500693.2021.1904523

Litman, J. (2005). Curiosity and the pleasures of learning: Wanting and liking new information. *Cognition and Emotion*, *19*(6), 793–814. https://doi.org/10.1080/02699930541000101

Liu, W., Li, X., & Li, G. (2023). The Contributions of Philosophy of Science in Science Education Research: a Literature Review. *Science & Education*. https://doi.org/10.1007/s11191-023-00485-w

Markula, A., & Aksela, M. (2022). The key characteristics of project-based learning: how teachers implement projects in K-12 science education. *Disciplinary and Interdisciplinary Science Education Research*, *4*(1), 2. https://doi.org/10.1186/s43031-021-00042-x

er, R. E. (2004). Should There Be a Three-Strikes Rule Against Pure Discovery Learning? *American Psychologist*, *59*(1), 14–19. https://doi.org/10.1037/0003-066X.59.1.14

er, R. E. (2009). *Multimedia Learning*. Cambridge University Press. https://doi.org/10.1017/CBO9780511811678

Nikolopoulou, K., Gialamas, V., Lavidas, K., & Komis, V. (2021). Teachers' Readiness to Adopt Mobile Learning in Classrooms: A Study in Greece. *Technology, Knowledge and Learning*, *26*(1), 53–77. https://doi.org/10.1007/s10758-020-09453-7

Noh, S. N. A., Azan, N., & Mohamed, H. (2020). Serious Games Requirements for Higher-Order Thinking Skills in Science Education. *International Journal of Advanced Computer Science and Applications*, *11*(6). https://doi.org/10.14569/IJACSA.2020.0110627

Nunnally, J. C. (1978). *Psychometric Theory (2nd ed.)*. McGraw-Hill.

Papadakis, S., Zourmpakis, A.-I., & Kalogiannakis, M. (2023). *Analyzing the Impact of a Gamification Approach on Primary Students' Motivation and Learning in Science Education* (pp. 701–711). https://doi.org/10.1007/978-3-031-26876-2_66

Parasuraman, A. (2000). Technology Readiness Index (Tri). *Journal of Service Research*, *2*(4), 307–320. https://doi.org/10.1177/109467050024001

Penuel, W. R., Bell, P., & Neill, T. (2020). Creating a system of professional learning that meets teachers' needs. *Phi Delta Kappan*, *101*(8), 37–41. https://doi.org/10.1177/0031721720923520

Plass, J. L., Homer, B. D., er, R. E., & Kinzer, C. K. (2020). *Theoretical foundations of game-based and playful learning*. The MIT Press.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., Kyza, E., Edelson, D., & Soloway, E. (2004). A Scaffolding Design Framework for Software to Support Science Inquiry. *Journal of the Learning Sciences*, *13*(3), 337–386. https://doi.org/10.1207/s15327809jls1303_4

Rossi, I. V., de Lima, J. D., Sabatke, B., Nunes, M. A. F., Ramirez, G. E., & Ramirez, M. I. (2021). Active learning tools improve the learning outcomes, scientific attitude, and critical thinking in higher education: Experiences in an online course during the <scp>COVID</scp> -19 pandemic. *Biochemistry and Molecular Biology Education*, *49*(6), 888–903. https://doi.org/10.1002/bmb.21574

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Rutten, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers & Education*, *58*(1), 136–153. https://doi.org/10.1016/j.compedu.2011.07.017

Ruzaman, N. K., & Rosli, D. I. (2020). Inquiry-Based Education: Innovation in Participatory Inquiry Paradigm. *International Journal of Emerging Technologies in Learning (IJET)*, *15*(10), 4. https://doi.org/10.3991/ijet.v15i10.11460

Ryan, R. M., & Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary Educational Psychology*, *61*, 101860. https://doi.org/10.1016/j.cedpsych.2020.101860

Schommer, M. (2019). *An emerging conceptualization of epistemological beliefs and their role in learning. In Beliefs about text and instruction with text*. Routledge.

Schommer-Aikins, M. (2004). Explaining the Epistemological Belief System: Introducing the Embedded Systemic Model and Coordinated Research Approach. *Educational Psychologist*, *39*(1), 19–29. https://doi.org/10.1207/s15326985ep3901_3

Schunk, D. H., & DiBenedetto, M. K. (2020). Motivation and social cognitive theory. *Contemporary Educational Psychology*, *60*, 101832. https://doi.org/10.1016/j.cedpsych.2019.101832

Suprapto, N., Prahani, B. K., & Cheng, T. H. (2021). Indonesian Curriculum Reform in Policy and Local Wisdom: Perspectives from Science Education. *Jurnal Pendidikan IPA Indonesia*, *10*(1), 69–80. https://doi.org/10.15294/jpii.v10i1.28438

Swarat, S., Ortony, A., & Revelle, W. (2012). Activity matters: Understanding student interest in school science. *Journal of Research in Science Teaching*, *49*(4), 515–537. https://doi.org/10.1002/tea.21010

Sweller, J. (2010). Element Interactivity and Intrinsic, Extraneous, and Germane Cognitive Load. *Educational Psychology Review*, *22*(2), 123–138. https://doi.org/10.1007/s10648-010-9128-5

Tashakkori, A., & Teddlie, C. (2010). *SAGE Handbook of Mixed Methods in Social & Behavioral Research*. SAGE Publications, Inc. https://doi.org/10.4135/9781506335193

Tsai, C.-C., Jessie Ho, H. N., Liang, J.-C., & Lin, H.-M. (2011). Scientific epistemic beliefs, conceptions of learning science and self-efficacy of learning science among high school students. *Learning and Instruction*. https://doi.org/10.1016/j.learninstruc.2011.05.002

von Stumm, S., Hell, B., & Chamorro-Premuzic, T. (2011). The Hungry Mind. *Perspectives on Psychological Science*, *6*(6), 574–588. https://doi.org/10.1177/1745691611421204

Yang, D., Cai, Z., Wang, C., Zhang, C., Chen, P., & Huang, R. (2023). Not all engaged students are alike: patterns of engagement and burnout among elementary students using a person-centered approach. *BMC Psychology*, *11*(1), 38. https://doi.org/10.1186/s40359-023-01071-z

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

International Journal of Science Education and Teaching
Vol. 4, No. 2, pp. 126-140, May. – Aug. 2025
http://doi.org/10.14456/ijset.2025.09

Learning Management Platform to Enhance Computational Thinking in Computer Science Using a Flipped Classroom Technique for 6th Grade Students

Phongsak Phakamach[1*], Sasirada Pangthai[2], Ritthidech Phomdee[3], Natchaya Sommartdejsakul[3]
[1]*Rattanakosin International College of Creative Entrepreneurship, Rajamangala University of Technology Rattanakosin, Thailand*
[2]*Faculty of Education, Pitchayabundit College, Thailand*
[3]*Advanced Future Talent Academy, Thailand*
*Email: phongsak.pha@rmutr.ac.th

Received: 22 Jun. 2025 Revised: 21 Jul. 2025 Accepted: 24 Jul. 2025

Abstract. The objectives of this research were: 1) to develop a learning management platform to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students; 2) to evaluate the efficiency of the learning management platform for enhancing computational thinking in computer science using a flipped classroom technique, according to the 80/80 standard criteria; 3) to determine the effectiveness index and learning achievement of the developed platform; and 4) to study the level of expert opinion on learning with the developed platform. The sample group consisted of 50 6th grade students from Assumption College Thonburi, Bangkok, selected through cluster random sampling with classrooms as the sampling unit, and 10 experts in educational innovation and technology selected using purposive sampling. The research instruments used were: 1) the learning management platform for enhancing computational thinking in computer science using a flipped classroom technique, 2) a learning achievement test, and 3) a platform quality evaluation form by experts. The statistics used for data analysis were percentage, mean, standard deviation, and *t*-test. The research revealed that the developed learning management platform for enhancing computational thinking in computer science using a flipped classroom technique had an efficiency of 81.55/83.98, which aligns with the 80/80 standard criteria. The effectiveness index was 0.8314. Students who learned with the system showed significantly higher post-test learning achievement than pre-test learning achievement at a statistical significance level of 0.05. Experts had a high level of opinion regarding the learning management platform for enhancing computational thinking in computer science using a flipped classroom technique. The research results yielded a prototype learning management platform to enhance computational thinking in computer science for 6th grade students that is efficient, can be practically used in teaching and learning, and enables learners to acquire skills and develop learning in computer science for subsequent science learning.

Keywords: Learning Management Platform; Computational Thinking; Computer Science; Flipped Classroom Technique

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

INTRODUCTION

The United Nations has established the Sustainable Development Goals (SDGs) for member states to achieve by 2030, focusing on social, economic, and environmental progress. Effective and high-quality education forms a crucial foundation for human resource development, which is fundamental to a nation's stable and sustainable growth. The National Education Act (No. 4) B.E. 2562 (2019) and the 13th National Economic and Social Development Plan B.E. 2566-2570 (2023-2027) have outlined key emphases for quality development, guiding curriculum, learning management, and assessment with the aim of significantly improving learner quality (Ministry of Education, 2019). Consequently, the Ministry of Education has mandated educational reform in line with the 20-year National Strategy, envisioning that "Thais will learn throughout life with quality." This systemic reform of education and learning primarily focuses on three key areas: enhancing the quality of education and learning, increasing educational opportunities and access to quality learning for all Thais, and fostering participation from all sectors of society. New guidelines have been established to develop quality across five areas: Thai citizens, teachers, learners, educational institutions, and administration. Specifically, basic education is encouraged to adapt learning models to be contemporary, implement systematic and clear operational plans for practical execution, and develop high-quality learning materials that respond to the evolving learning situations in the digital education era (Ministry of Education, 2023).

Learning Management Systems (LMS), including teaching and learning management using Digital Platforms, are methods employed to enhance potential and solve problems in current learning, where learning styles and methods must be blended for maximum quality. This allows instructors to prepare lessons with diverse learning media, enables learners to review content retrospectively, and provides learners with access to learning resources anytime, anywhere via designed online channels. Clear teaching objectives are set, pedagogical theories guide management, and content is presented in multimedia format through systematic network and educational platforms. This helps learners acquire new knowledge and skills or significantly improve their existing knowledge and abilities (Kant et al., 2021; Samaila & Al-Samarraie, 2024). Additionally, digital platforms can enable learners to learn independently, providing immediate and effective feedback, allowing learners to know their learning progress quickly. They can also help increase learner motivation through program design that includes images, sounds, multimedia, and fast interaction with learners. The era of transformative education (Education Disruption) has brought diverse learning management models to promote and solve various educational challenges. Therefore, learning management must adapt to new learning paradigms, enabling learners to be self-directed in seeking knowledge, especially in fully utilizing educational innovations and technologies for knowledge acquisition (Sinlarat, 2020; Phakamach, 2023; Phakamach et al., 2024a).

Computational Thinking (CT) refers to a systematic, step-by-step problem-solving process applicable by both humans and computers. The benefits of CT include: 1) simplifying complex problems, 2) enhancing problem comprehension, 3) effectively communicating concepts to others, 4) providing a foundation for computer programming, and 5) developing systematic thinking skills (Tsortanidou et al., 2019; Weinhandl et al., 2020; Ramírez-Montoya & Portuguez-Castro, 2024). CT benefits learning by helping learners to: 1) better comprehend and solve computational science problems, 2) apply these concepts to real-world problems, and 3) develop creative thinking and problem-solving skills. Practical applications of CT, particularly within a STEM approach for daily life situations, include travel planning, time management, solving mathematical problems, and computer programming. Therefore, computational thinking is an essential skill for problem-solving and fostering intellectual development in the digital education era, enabling learners to grasp and apply these concepts across diverse situations (Champion et al., 2020; Lai, 2024; Hidayat et al., 2024). The Flipped Classroom model has also been widely adopted to enhance teaching and learning and address educational challenges in an era characterized by diverse information sources and ICT media (Jian, 2018; Nachatar Singh et al., 2019). This is because the flipped classroom learning model focuses on students' knowledge construction based on their individual skills, knowledge, abilities, and intelligence. It also empowers learners with freedom in thought and methods for seeking knowledge from external learning resources, fostering analytical thinking, problem-solving,

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

creativity, and student interaction. Its emphasis on inquiry-based, learner-centered instruction promotes and supports students, perfectly aligning with contemporary educational shifts (Weinhandl et al., 2020; Latorre-Cosculluela et al., 2021; Chaisena et al., 2022; Hwang et al., 2023; Suwardika et al., 2024).

Furthermore, in the 21st century, the learning paradigm has shifted the teacher's role from that of a lecturer to a facilitator of the learning process, designing pedagogical activities that empower students to independently learn and construct knowledge. As a facilitator, the teacher guides students and suggests tools for efficient and seamless knowledge access and learning activities through various methods, especially via technology or learning management systems (Phakamach, 2023). This acquired knowledge is then exchanged with peers in the classroom, a learning process known as Active Learning, which is student-centered. Moreover, the flipped classroom model is widely discussed and applied today due to its ability to foster 21st Century Skills by leveraging modern educational technology and offering learners opportunities for diverse activities (Smith, 2021). Therefore, applying the flipped classroom model in conjunction with a learning management system, particularly for practical computational courses, can significantly enhance the efficiency and effectiveness of science education, leading to improved student learning outcomes (Jian, 2018; Ironsi, 2022; Pereira Bueno et al., 2023; Samaila & Al-Samarraie, 2024; Suwardika et al., 2024).

Based on these concepts, the researchers are interested in developing a learning management platform to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students, employing a Research and Development (R&D) methodology. This aims to create a learning management platform that enhances computational thinking in computer science using a flipped classroom technique for 6th grade students, applying educational innovation and technology as supplementary tools in managing instruction for this subject. The process involves blended online learning network management, used for conducting teaching and learning activities in computer science, creating a digital for learning environment based on computational thinking. It is expected that the developed platform and learning management model will help primary school students learn collaboratively in the classroom to enhance their computational learning competencies, achieve learning outcomes quickly, and serve as a guideline for spreading knowledge in schools that use ICT systems and educational innovations in their teaching.

RESEARCH OBJECTIVES

The study had four research objectives were as follows:

1. To develop a learning management platform to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students.

2. To evaluate the efficiency of the developed learning management platform for enhancing computational thinking in computer science using a flipped classroom technique, according to the 80/80 standard criteria.

3. To determine the effectiveness index and learning achievement of the learning management platform for enhancing computational thinking in computer science using a flipped classroom technique.

4. To study the level of expert opinion on learning with the learning management platform to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students.

LITERATURE REVIEW

The 21st century is characterized by rapid technological advancements and a growing emphasis on digital literacy and critical thinking skills. In this context, computational thinking (CT) has emerged as a fundamental skill set crucial for navigating and contributing to the modern world. Recognizing its importance, educational systems globally, including Thailand, are integrating computer science (CS) concepts into primary education curricula. This literature review explores the interconnected roles of Learning Management Platforms (LMPs) and the flipped classroom (FC) technique as a synergistic pedagogical approach to enhance computational thinking skills specifically in 6th-grade students studying computer science.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

The Imperative for 21st Century Skills and Computational Thinking

The United Nations' Sustainable Development Goals (SDGs) and national educational policies, such as Thailand's National Education Act (No. 4) B.E. 2562 (2019) and the 13th National Economic and Social Development Plan B.E. 2566-2570 (2023-2027), underscore the critical need for quality education to develop human resources capable of fostering sustainable societal progress. This involves systemic educational reform, focusing on improving learning quality, expanding educational opportunities, and ensuring access to quality learning for all (Ministry of Education, 2019, 2023). A core aspect of this reform is adapting learning models to current situations and producing high-quality teaching media responsive to the digital education era (Phakamach et al., 2024a).

Central to this educational evolution is computational thinking, defined as a problem-solving process that employs systematic and step-by-step methods, applicable by both humans and computers. CT encompasses key components such as decomposition, pattern recognition, abstraction, and algorithmic thinking (Tsortanidou et al., 2019; Weinhandl et al., 2020; Ramírez-Montoya & Portuguez-Castro, 2024). For 6th-grade students, CT is not merely about programming but about developing a logical, analytical, and creative approach to problem-solving. Its benefits extend to simplifying complex problems, enhancing problem comprehension, improving communication of ideas, building foundational programming skills, and fostering systematic thinking. Moreover, CT supports creative thinking and problem-solving in various real-life scenarios, such as travel planning, time management, and mathematical problem-solving, making it an indispensable skill in the digital age (Champion et al., 2020; Lai, 2024; Hidayat et al., 2024).

The Flipped Classroom Model in Educational Transformation

The landscape of education is undergoing significant transformation, often termed "Education Disruption," demanding flexible and innovative instructional models. The flipped classroom model stands out as a prominent approach addressing these demands. It inverts the traditional learning setup by moving direct instruction outside the classroom (e.g., through pre-recorded videos, online readings) and dedicating in-class time to active, hands-on activities, problem-solving, and collaborative learning (Jian, 2018; Nachatar Singh et al., 2019).

For primary school students, the flipped classroom model offers several advantages. It empowers students to construct knowledge based on their individual skills, abilities, and intelligence, providing freedom in thought and knowledge acquisition from external learning resources. This fosters analytical thinking, problem-solving, creativity, and interaction among learners. By emphasizing inquiry-based, student-centered learning, the flipped classroom aligns well with contemporary educational paradigms (Weinhandl et al., 2020; Latorre-Cosculluela et al., 2021; Chaisena et al., 2022; Hwang et al., 2023; Suwardika et al., 2024). In the 21st century, the teacher's role shifts from a lecturer to a facilitator and activity designer, guiding students to construct knowledge through active learning and collaborative engagement (Phakamach, 2023). This model is particularly effective in cultivating 21st century skills by leveraging modern instructional technology and providing diverse learning activities (Smith, 2021; Leão et al., 2023).

The Role of Learning Management Platforms

Learning Management Systems (LMS) and Digital Platforms are integral components of modern educational ecosystems, providing a robust infrastructure to support enhanced learning experiences. These platforms are crucial for addressing contemporary learning challenges, particularly when integrating diverse teaching methods for optimal quality. They empower instructors to organize a variety of learning media, enable students to review content at their convenience, and facilitate ubiquitous access to learning resources online (Kant et al., 2021; Samaila & Al-Samarraie, 2024).

LMPs are designed with clear instructional objectives, guided by pedagogical theories, and present content through multimedia formats via systematic educational networks and platforms. This systematic approach effectively promotes knowledge acquisition and skill development or improvement (Phakamach et al., 2024b). Moreover, digital platforms support independent learning by providing immediate and effective feedback, allowing learners to track their progress quickly.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Features like engaging visuals, sounds, and interactive multimedia can significantly boost student motivation (Jian, 2018; Zainuddin et al., 2019; Chaisena et al. 2022; Lantu et al., 2023; Suwardika et al., 2024). The flexibility and rich features of LMPs make them essential tools for implementing blended learning and flipped classroom models, especially in subjects like computer science that benefit from interactive and self-paced learning.

Integrating the Flipped Classroom and Learning Management Platforms for Computational Thinking in 6th Grade Computer Science

The synergy between the flipped classroom model and learning management platforms offers a powerful approach to enhancing computational thinking in computer science for 6th-grade students. The LMP serves as the primary conduit for delivering pre-class instructional content, including foundational concepts of computational thinking, interactive tutorials, and virtual learning media. This pre-engagement allows students to absorb basic knowledge at their own pace, ensuring they arrive in the classroom with a shared baseline understanding.

In the classroom, the freed-up time can be dedicated to active learning activities and collaborative problem-solving, where students apply their newfound CT skills. This can involve hands-on coding challenges, debugging exercises, or group projects that require logical reasoning and algorithmic thinking. The teacher transitions into a facilitator role, providing personalized guidance, clarifying misconceptions, and fostering deeper conceptual understanding. The LMP further supports this by providing tools for practice exercises, tracking student progress, and offering instant feedback, which is crucial for the iterative development of CT skills (Leão et al., 2023).

Research indicates that the systematic development of such integrated learning environments, following models like ADDIE (Analysis, Design, Development, Implementation, Evaluation), and incorporating expert reviews, leads to highly effective platforms. Studies show that learning management platforms designed with active learning components, engaging multimedia, and robust support systems can significantly improve student engagement, learning achievement, and the acquisition of computational thinking skills (Chaisena et al., 2022; Ironsi, 2022; Lantu et al., 2023; Hwang et al., 2023; Leão et al., 2023; Phakamach et al., 2024b; Samaila & Al-Samarraie, 2024; Suwardika et al., 2024). The positive impact on learning outcomes, as evidenced by significant gains in post-test scores and high effectiveness indices, underscores the potential of this integrated approach. From previous research reports, it can also be concluded that ADDIE significantly contributes to student learning outcomes at each stage, as follows: 1) Analysis: Helps in understanding learner needs and clarifying learning objectives, leading to precisely defined learning outcome goals; 2) Design: Involves planning content structure, instructional strategies, and activities that align with objectives, enabling learners to achieve the set outcomes; 3) Development: Creates learning materials and platforms according to the design, providing appropriate tools to facilitate learning; 4) Implementation: Applies the developed plans and materials in the actual learning environment, facilitating learner engagement; and 5) Evaluation: Assesses the effectiveness of the learning and the platform to identify strengths, weaknesses, and make continuous improvements for enhanced learning outcomes. Furthermore, positive expert opinions on the platform’s components, design, and usability confirm its quality and suitability for practical implementation in 6th-grade computer science education.

In summary, the integration of a learning management platform with the flipped classroom technique presents an effective and efficient pedagogical model for enhancing computational thinking in 6th-grade computer science students. This approach aligns with national educational goals and the global imperative for developing 21st century skills. By enabling flexible pre-class learning and maximizing in-class time for active, collaborative application of computational thinking, this integrated model fosters deeper understanding, improves learning outcomes, and cultivates essential problem-solving abilities. The consistent positive findings from various studies and expert evaluations support the viability and quality of such platforms. As education continues to evolve, further research and development in this area will be crucial to refine these models and expand modern scientific learning resources for basic education.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

RESEARCH CONCEPTUAL FRAMEWORK

Based on the literature review, documents, articles, and various related research reports, the researchers designed the research methodology by defining a conceptual framework for developing a learning management platform to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students, as shown in Figure 1.

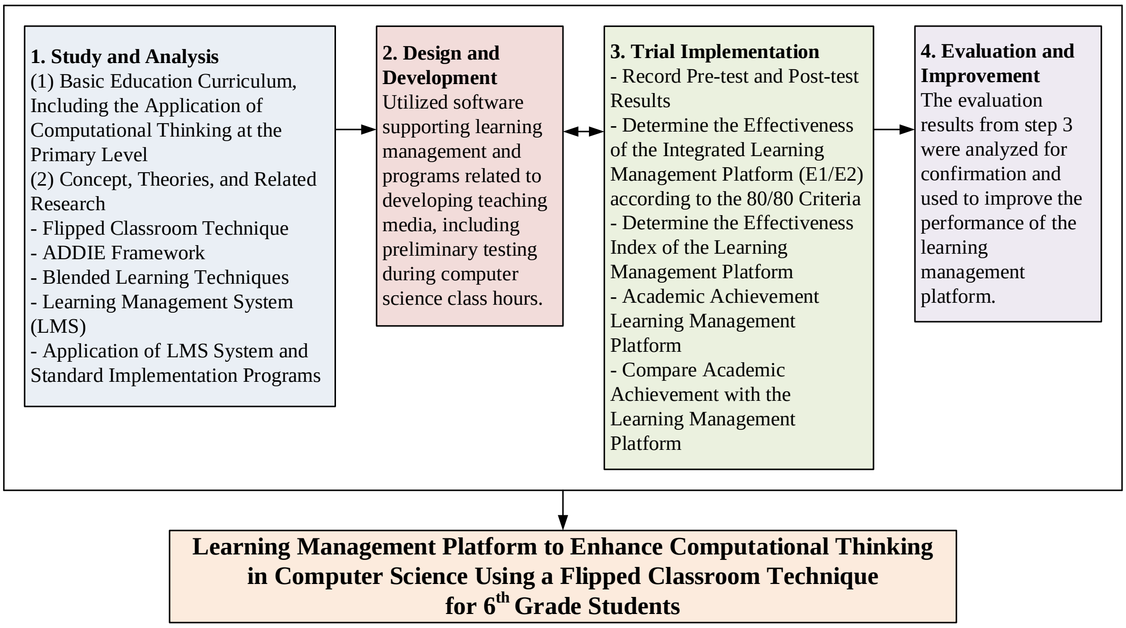


Figure 1: Research Conceptual Framework.

METHODOLOGY

This research includes research and development with related details as follows:

Population and Sample

The population for this research consisted of 50 primary school students enrolled in the Computer Science course during the first semester of the academic year 2025 at Assumption College Thonburi, Bangkok. The sample was obtained through cluster random sampling of mathematics and science classrooms, with the classroom as the sampling unit. Additionally, 10 experts in educational innovation and technology were chosen via purposive sampling.

Research Instruments

The research instruments included: (1) the LMP developed to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students, (2) a learning achievement test, (3) a system quality evaluation form completed by experts, and (4) an expert opinion questionnaire and interview guide regarding the LMP for enhancing computational thinking in computer science using a flipped classroom technique for 6th grade students. This was informed by the research of Chaisena et al. (2022), Hwang et al. (2023), and Lai (2024).

The construction and validation of the questionnaire instruments involved presentation to experts to check content validity, as well as the appropriateness of language and wording. An Index of Item-objective Congruence (IOC) score of 0.91 was obtained. The questionnaire was then piloted, and its reliability was determined using Cronbach's Alpha Coefficient, yielding an overall questionnaire reliability of 0.937. The item discrimination was calculated using the Item Total Correlation.

Research Procedure

As this research employed a Research and Development (R&D) methodology, the researchers outlined four sequential steps to cover the research objectives:

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

1. Study and Analysis: This involved studying and analyzing data related to the basic education curriculum, including the application of computational thinking at the primary level, drawing from relevant documents and research reports.

2. Design and Development: This phase utilized software supporting learning management and programs related to developing teaching media, including preliminary testing during computer science class hours.

3. Trial Implementation: This stage involved a 3-month trial period to test efficiency, calculate the effectiveness index, and measure the learning achievement of students enrolled in the computer science course.

4. Evaluation and Improvement: The evaluation results from step 3 were analyzed for confirmation and used to improve the performance of the learning management platform designed to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students, ensuring it met specified performance criteria.

Steps for Creating Online Learning Instruments

The steps for creating online learning instruments included: (1) studying the curriculum/course and analyzing the content of the Computer Science course, (2) defining learning objectives to determine the scope of content for each learning unit, (3) defining the content presentation format, (4) writing a Flowchart for the lessons to define internal communication channels, (5) designing a Storyboard based on a hierarchical structure using the flipped classroom model, (6) developing the format using the LMS Tool Box and computer programs, (7) piloting and revising the format, and (8) evaluating the quality and efficiency of the developed platform.

Experiment and Data Collection

1. Location: The experiment was conducted at Assumption College Thonburi, Bangkok.

2. Preparation for the Experiment included: (1) obtaining permission to collect data and pilot the system, (2) preparing the developed system for online website deployment, uploading data to the server, and testing its functionality, and (3) preparing the venue, computers, connection equipment, and scheduling the experiment time.

3. Conducting the Experiment: The system, after expert evaluation, was piloted to assess its efficiency using the following experimental designs (Fernández et al., 2016):

3.1 One-to-One Testing: Conducted with 3 students who had previously taken the course, selected by simple random sampling. Efficiency (E_1/E_2) was evaluated to identify flaws and make improvements, yielding an E_1/E_2 value of 61.36/62.19.

3.2 Small Group Testing: Conducted with 9 students who had previously enrolled in the course, selected by simple random sampling. Efficiency (E_1/E_2) was evaluated to identify flaws and make improvements, yielding an E_1/E_2 value of 71.45/72.58.

3.3 Field Testing: Conducted with a sample group of 50 students, following these steps: (1) A Pretest was administered using a 40-item learning achievement test. (2) Students learned using the developed platform. (3) Students completed exercises from the developed platform, 10 items per learning unit. (4) A Posttest was administered using the same 40-item learning achievement test. The overall efficiency (E_1/E_2) was evaluated, yielding an E_1/E_2 value of 81.55/83.98.

Data Analysis

The researchers analyzed the collected data using statistical computer programs, as follows:

1. Development of the LMP to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students involved:

1.1 Evaluation of a learning management platform's quality, assessed by 10 educational innovation and technology experts using a 5-point Likert scale. The interpretation criteria were:

4.51 – 5.00: Highest quality;
3.51 – 4.50: High quality;
2.51 – 3.50: Moderate quality;
1.51 – 2.50: Low quality; and

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

1.00 – 1.50: Lowest quality.

1.2 Efficiency analysis of the platform included: (1) calculating basic statistics (percentage, mean score, and standard deviation) from each learning unit's test scores and post-learning achievement scores, (2) determining efficiency according to the 80/80 criteria, (3) calculating the effectiveness index, (4) comparing pre-test and post-test learning achievement using *t*-test statistics, and (5) analyzing expert opinions on learning with the platform by calculating the mean ($\bar{x}$) and standard deviation (S.D) and comparing the mean to the set criteria using a 5-point Likert scale.

2. Statistics used to determine the quality of the learning achievement test included: (1) Discrimination index using Brennan's criterion-referenced analysis, (2) Difficulty level, (3) Content validity of each test item using the IOC formula, and (4) Reliability of the test using Kuder-Richardson's KR20 formula.

3. Statistics used to calculate the effectiveness index employed Goodman, Fletcher, and Schneider's method.

4. Calculation of the efficiency of the platform according to the 80/80 standard criteria used a specific formula.

5. Comparison of the difference between pre-test and post-test scores used a dependent samples *t*-test with its corresponding formula.

6. Data from the interviews and expert discussions were analyzed using descriptive content analysis.

RESULTS

Based on the research titled "Learning Management Platform to Enhance Computational Thinking in Computer Science Using a Flipped Classroom Technique for 6th Grade Students," the research findings and data analysis, aligned with the research objectives, are as follows:

1. Results of Developing the Learning Management Platform

The developed LMP to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students was designed using a LMS that incorporates computer science content. It aims to strengthen computational thinking as a foundation, preparing students with knowledge and interest in higher levels of science and technology. Additionally, the flipped classroom technique is employed to enable students to practice learning outside of regular class hours through virtual learning content and media. Therefore, the platform's design, based on the presented methodology, ensures sufficient quality for its practical implementation.

2. Results of Evaluating the Platform's Efficiency

The evaluation of the LMP's efficiency in enhancing computational thinking in computer science using a flipped classroom technique for 6th grade students, which met the 80/80 standard criteria, revealed an efficiency of 81.55/83.98. This means that the developed platform facilitated a learning process efficiency of 81.55% and a learning performance efficiency (change in student behavior) of 83.98%. Thus, it met the 80/80 standard criteria as intended by the research objectives.

3. Results of Determining the Effectiveness Index and Learning Achievement

The effectiveness index of the developed LMP to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students was 0.8314 (83.14%). Regarding the learning achievement of students who learned with the developed platform, the average pre-test score was 15.64 out of a total of 30, equivalent to 50.46%. The average post-test score was 23.87 out of a total of 30, equivalent to 73.45%. When the obtained average scores were subjected to a *t*-test (t=22.471), it was found that the post-test scores were significantly higher than the pre-test scores at a statistical significance level of 0.05, as shown in Table 1.

Table 1: Comparison of Students' Learning Achievement Before and After Learning.

Learning Achievement	*n*	$\bar{x}$	S.D.	*t*	*p*-value
Pretest	50	15.64	0.574	22.471	.001
Posttest	50	23.87	0.628		

* Statistically significant at the level of .05.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

4. Expert Opinion on Platform Quality Evaluation Results

The results of the study to evaluate the quality based on the opinions of 10 experts in educational innovation and technology regarding the LMP to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students as shown in Table 2.

Table 2: Expert Evaluation Results of Platform Quality.

Topics and Assessment Items		$\bar{x}$	S.D.	Interpreting
System Components and Learning Activities	1. Learning Management Platform	4.10	0.60	High
	2. Record knowledge	4.00	0.55	High
	3. Measuring and evaluating knowledge	4.13	0.65	High
	4. Discussion board	4.10	0.55	High
	5. Knowledge repository and exchange	4.20	0.50	High
	6. Active learning activities	4.44	0.65	Highest
	7. Pictures of various activities	4.32	0.60	Highest
Design and Development	8. Content and Consistency	4.38	0.65	Highest
	9. Format and font size	3.99	0.55	High
	10. Font color and background	4.04	0.60	High
	11. Visual and sound effects	4.23	0.55	High
	12. Multimedia system	3.69	0.65	High
	13. Instructions and Manuals	4.24	0.60	High
	14. Overall screen interface and activities	4.35	0.55	Highest
	15. Design and development process	4.29	0.60	Highest
Usability and Attitude	16. Membership system	4.04	0.50	High
	17. Back-end system	4.14	0.65	High
	18. Link section with AI interface	4.40	0.55	Highest
	19. Interaction section	3.90	0.65	High
	20. Search system	4.32	0.50	Highest
	21. How to use it for the purpose	4.44	0.65	Highest
	22. Practice in the course	4.17	0.60	High
Total		**4.17**	**0.55**	**High**

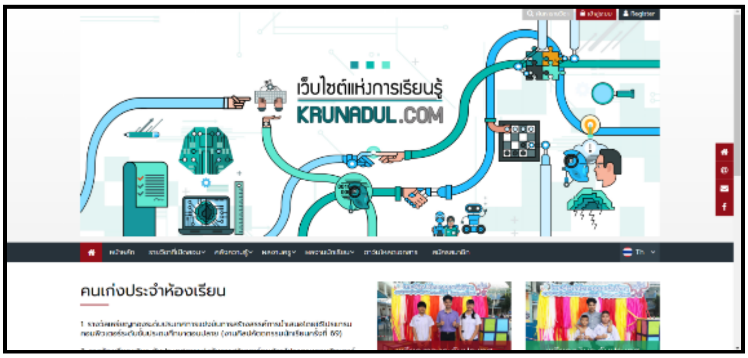
From table 2, the quality evaluation of the LMP to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students, assessed by experts across three dimensions, revealed an overall average quality at a high level ($\bar{x}$= 4.17). When considering each dimension, the findings were as follows: System Components and Learning Activities (7 items): The overall average was at a high level ($\bar{x}$= 4.18). Ranking the average scores from highest to lowest: 1) Active learning activities, 2) Pictures of various activities, and 3) Knowledge repository and exchange. Design and Development (8 items): The overall average was at a high level ($\bar{x}$= 4.15). Ranking the average scores from highest to lowest: 1) Content and Consistency, 2) Overall screen interface and activities, and 3) Design and development process. Usability and Attitude (7 items): The overall average was at a high level ($\bar{x}$ =4.20). Ranking the average scores from highest to lowest: 1) How to use it for the purpose, 2) Link section with AI interface, and 3) Search system.

Furthermore, the focus group discussions with 10 experts in educational innovation and technology centered on five key areas: (1) design and development processes, (2) content and presentation, (3) learning activities and problem-solving, (4) implementation, and (5) recommendations. The experts collectively confirmed that the developed learning management platform adheres to standard design and development processes and can effectively be used for instruction within the subject, potentially through a blended learning approach. Moreover, the platform's design and development process can serve as a prototype for other schools to develop their own learning management models. However, the experts also suggested that for future educational terms, the content and learning activities should be further developed with more case

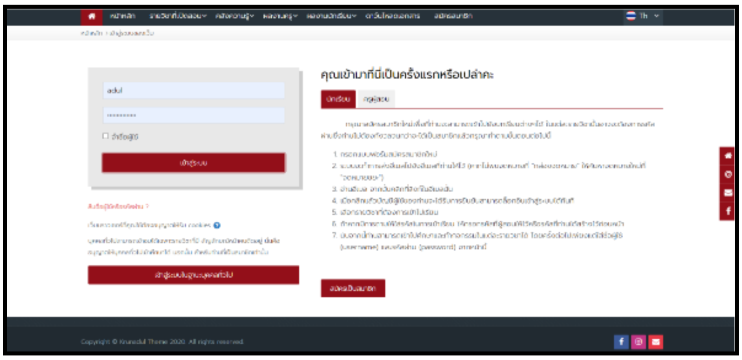
©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

studies to help students achieve the subject's learning outcomes, foster positive computational thinking development, and encourage greater educational innovation.

Examples of the improved LMP to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students as shown in Figures 2-6. These include, respectively: Figure 2: Learning Management Platform to Enhance Computational Thinking in Computer Science Using a Flipped Classroom Technique for 6th Grade Students where (a) is homepage of platform and (b) is login window of platform, Figure 3: Computer Science Learning Units for 6th Grade, Figure 4: Example of Learning Unit Components, Figure 5: Example of Learning Skill Practice Activities, and Figure 6: Example of Online Teaching and Learning Activities.



(a) Homepage of Platform



(b) Login Window of Platform

Figure 2: Learning Management Platform to Enhance Computational Thinking in Computer Science Using a Flipped Classroom Technique for 6th Grade Students.

Figure 3: Computer Science Learning Units for 6th Grade.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

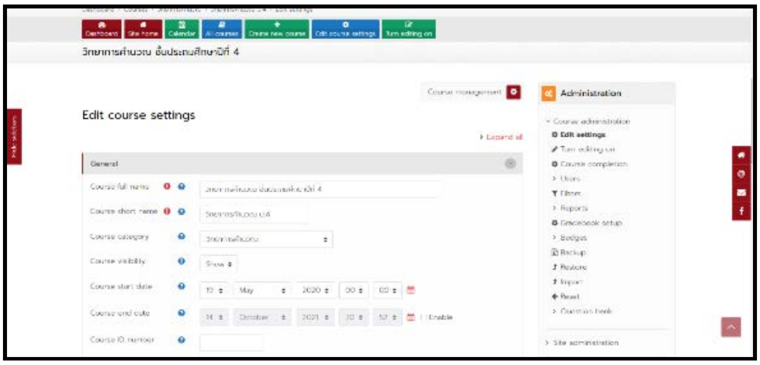


Figure 4: Example of Learning Unit Components.

Figure 5: Example of Learning Skill Practice Activities.

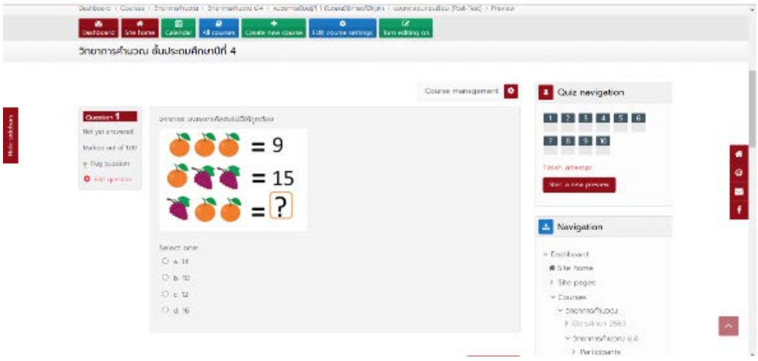


Figure 6: Example of Online Teaching and Learning Activities.

CONCLUSION AND DISCUSSION

Based on the research project titled "Learning Management Platform to Enhance Computational Thinking in Computer Science Using a Flipped Classroom Technique for 6th Grade Students," the research findings and data analysis could be summarized and discussed in alignment with the objectives and research procedures were as follows:

1. Development of the Learning Management Platform

The developed LMP to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students was designed by the researchers based on conceptual frameworks from Jian (2018), Zainuddin et al. (2019), Champion et al. (2020), Chaisena et al. (2022), Hwang et al. (2023), Phakamach et al. (2024b), and Samaila and Al-Samarraie (2024) for LMS design. The key design principles included: 1) content analysis of the subject, 2) instructional design based on flipped classroom principles utilizing collaborative learning (which involved: (1) studying the problem to be analyzed, (2) gathering and processing the problem, (3) developing possible solutions, (4) testing the solutions, and (5) selecting the best learning model to find answers), 3)

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

defining joint activities and knowledge processing, 4) conducting instruction with models and teaching media using designated communication channels, and 5) testing the efficiency of the learning model by considering learning achievement scores and end-of-chapter exercise scores.

2. Efficiency of the Learning Management Platform

The results from testing the efficiency of the developed LMP to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students showed an efficiency of 81.44/83.89. This means that the LMP led to an 81.44% efficiency in the learning process and an 83.89% efficiency in learning (or the effectiveness of the learning model and teaching media in changing student behavior). This demonstrated that the developed platform met the 80/80 standard criteria and could satisfactorily help students improve their learning progress in computer science. These findings were consistent with the research of Chaisena et al. (2022), Ironsi (2022), Lantu et al. (2023), Hwang et al. (2023), Errabo et al. (2024), and Şahin and Kılıç (2025). This could be attributed to the following reasons:

2.1 The LMP had average scores higher than the set standard criteria. This was because the researchers systematically developed the LMS, from studying and analyzing data using the ADDIE model process to designing computer science content based on the flipped classroom activity design steps that enhance computational thinking. This content was reviewed and revised by subject matter experts. Subsequently, it was reviewed by educational innovation and technology experts before being piloted with the sample group to evaluate its efficiency and improve it based on the results. This aligns with the media production and learning model development process of Research and Development (R&D). The used of standard LMS Tool Boxes for creating content, problems, and interactive components in the computer science classroom is consistent with the research of Jian (2018), Chaisena et al. (2022), Hwang et al. (2023), Leão et al. (2023), Phakamach et al. (2024b), Samaila and Al-Samarraie (2024), and Suwardika et al. (2024). Therefore, 6th grade students gained a better understanding of computer science learning.

2.2 The developed LMP included robust learning management support and tracking systems to ensure students achieved the specified computational thinking learning outcomes, covering content, research, knowledge processing, discussion, critical thinking, and collaborative conclusions.

3. Effectiveness Index and Learning Achievement

The effectiveness index of the developed LMP to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students was 0.8314. This means that after learning with this platform, scores increased by 83.14%. This finding was consistent with the research of Jian (2018), Zainuddin et al. (2019), Chaisena et al. (2022), and Hwang et al. (2023). This was because the platform’s presentation format mimics direct instruction from a teacher. It enhanced understanding through collaborative learning processes, incorporating text, graphics, still images, animations, and multimedia, making learning enjoyable and engaging for students. It also provided reinforcing feedback, drawing from Malone’s motivation theory, where the instructional design included challenging activities and situations with critical learning objectives. Students’ imagination was stimulated, and novel presentations continuously capture their attention, fostering curiosity and a desire to learn new things (Jian, 2018; Zainuddin et al., 2019; Chaisena et al. 2022; Lantu et al., 2023; Suwardika et al., 2024). For these reasons, 6th grade students gained more knowledge and understanding in computer science, including its application in subsequent learning levels.

4. Expert Opinion on Platform Quality

The results of the quality evaluation based on expert opinions regarding learning with the developed LMP to enhance computational thinking in computer science using a flipped classroom technique for 6th grade students revealed that experts rated the learning components and activities dimension at a high level ($\bar{x}$=4.18). This indicated that the flipped classroom learning components and activities used to create the learning management platform were appropriate and could create an efficient LMP. This was consistent with the research of Jian (2018), Smith (2021), Chaisena et al. (2022), Lantu et al. (2023), Hwang et al. (2023), and Suwardika et al. (2024). The design and development dimension were also rated at a high level ($\bar{x}$=4.15), indicating that the design process can create a good and appropriate quality LMP. Furthermore, the usability and attitude dimension

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

were also rated at a high level ($\bar{x}$=4.20), clearly showing that the usability and student attitudes towards learning with the developed platform, including the media used, were appropriate and genuinely facilitate learning. This aligned with the research of Smith (2021), Bin-Hady and Hazaea (2022), Lantu et al. (2023), Hwang et al. (2023), Samaila and Al-Samarraie (2024), and Suwardika et al. (2024). This was because student attitude towards the lesson was crucial for improving the quality of the system and media used, providing clearer insights into students' actual needs. Allowing students to choose what they learn independently is part of a good learning process and leads to better learning through collaborative classroom experiences.

Therefore, it could be concluded that the research and development on "Learning Management Platform to Enhance Computational Thinking in Computer Science Using a Flipped Classroom Technique for 6th Grade Students," as presented, ensured sufficient quality for the practical implementation of this platform for learning management in computer science for 6th grade students. It could serve as a prototype for blended learning through offline and online processes, and this learning management model could be further developed to be completer and more efficient in the future.

RECOMMENDATIONS

The researchers put forward two kinds of feedback as follows:

Recommendations for Implementation and Development

1) For the implementation and further enhancement of the LMP's performance, the following are recommended: (1) Lesson content must align with objectives and learning outcomes, (2) Learning objectives and problems should be clearly communicated to learners, (3) There should be a well-designed structure and clear learning path planning, (4) A system to verify that learners achieve learning outcomes and solve assigned problems is essential, (5) Learners should be encouraged to engage in Non-Linear Approach and Active Learning, (6) The platform should be developed to foster analytical and critical thinking, (7) Regular practical exercises with immediate feedback should be provided, (8) Access data, knowledge processing results, and usage should be recorded in a standardized format, and (9) In developing online learning systems, appropriate and consistent use of text, graphics, and multimedia is crucial to ensure efficient situational learning and information processing.

2) Before implementing this platform with elementary students at other schools, it's crucial to introduce the platform's format and processes to students. This will ensure they can use the platform and participate in classroom activities effectively, aligning with the objectives for teaching computational thinking.

3) To implement and assess CT to meet standards, focus on clear and measurable approaches:

(1) Clear Definition and Integration: CT components (decomposition, pattern recognition, abstraction, algorithms) should be clearly defined and integrated into curricula across various subjects, not just computer science. Specific learning outcomes should be identified, and activities designed to apply CT in diverse contexts, ensuring systematic understanding and practice.

(2) Practical and Problem-Solving Focused Learning Activities: Implement hands-on, problem-based learning activities where students actively apply CT skills through projects, coding, or complex problem-solving. Activities should encourage continuous critical thinking, planning, and refinement of solutions, which are core to CT development.

(3) Specific and Concrete Assessment: Assessment should directly measure CT skills beyond general achievement tests. Standard practices include using rubrics to evaluate code quality, problem-solving structure, or algorithm design. Additionally, observing behavior during problem-solving, analyzing student work, and using assessments specifically designed to measure individual CT components will yield accurate and reliable evaluation data.

Recommendations for Future Research

Recommendations for future research include:

1) Further development of this learning management platform to incorporate more standard learning media components, which would yield deeper insights for improving the efficiency of the learning management model.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

2) Research and development of digital platforms that utilize Blended Learning and HyFlex models, capable of fostering more positive feelings and imagination in online learners through improved and more engaging multimedia.

3) The research should be conducted by piloting this developed platform with students from other educational institutions who are studying the same subject and have similar characteristics. This will provide comparative data for further developing the quality of this platform to be even more efficient and effective.

4) Further research and development of platforms or learning management models for other subjects to expand modern scientific learning resources for the continued development of basic education in Thailand.

ACKNOWLEDGEMENTS

The authors are grateful to acknowledge the support of Rattanakosin International College of Creative Entrepreneurship, Rajamangala University of Technology Rattanakosin and Advanced Future Talent Academy, Thailand.

REFERENCES

Bin-Hady, W.R.A., & Hazaea, A.N. (2022). EFL students' achievement and attitudes towards flipped pronunciation class: correlational study. PSU Research Review, 6(3), 175-189.

Chaisena, A., Wachirawongpaisarn, S., & Phakamach, P. (2022). Online learning management system on visual arts using flipped classroom technique for prathomsuksa 4 students. Journal of Education and Innovative Learning, 2(1), 51–67.

Champion, D.N., Tucker-Raymond, E., Millner, A., Gravel, B., Wright, C.G., Likely, R., Allen-Handy, A., & Dandridge, T.M. (2020). Designing for learning computational STEM and arts integration in culturally sustaining learning ecologies. Information and Learning Sciences, 121(9/10), 785-804. https://doi.org/10.1108/ILS-01-2020-0018

Errabo, D.D., Paguio, A.J., & Enriquez, P.A. (2024). Epistemic fluency in virtual laboratories as flipped classroom's innovative learning delivery. Journal of Research in Innovative Teaching & Learning, 17(2), 256-281. https://doi.org/10.1108/JRIT-03-2024-0052

Fernández Cruz, F.J., Egido Gálvez, I., & Carballo Santaolalla, R. (2016). Impact of quality management systems on teaching-learning processes. Quality Assurance in Education, 24(3), 394-415. https://doi.org/10.1108/QAE-09-2013-0037

Hidayat, R., Nugroho, I., Zainuddin, Z., & Ingai, T.A. (2024). A systematic review of analytical thinking skills in STEM education settings. Information and Learning Sciences, 125(7/8), 565-586. https://doi.org/10.1108/ILS-06-2023-0070

Hwang, W.-Y., Nurtantyana, R., & Hariyanti, U. (2023). Collaboration and interaction with smart mechanisms in flipped classrooms. Data Technologies and Applications, 57(5), 625-642. https://doi.org/10.1108/DTA-04-2022-0171

Ironsi, C.S. (2022). A switch from flipped classrooms to emergency remote online teaching (EROT), misconceptions, instructors and preservice teachers perceptions. International Journal of Information and Learning Technology, 39(1), 13-28. https://doi.org/10.1108/IJILT-10-2020-0195

Jian, Q. (2018). Effects of digital flipped classroom teaching method integrated cooperative learning model on learning motivation and outcome. The Electronic Library, 37(5), 842-859. https://doi.org/10.1108/EL-02-2019-0024

Kant, N., Prasad, K.D., & Anjali, K. (2021). Selecting an appropriate learning management system in open and distance learning: a strategic approach. Asian Association of Open Universities Journal, 16(1), 79-97. https://doi.org/10.1108/AAOUJ-09-2020-0075

Lai, Y.H. (2024). Learning efficacy of understanding by design-Internet of Things (UbD-IoT) education integrated with design thinking and computational thinking. Library Hi Tech, 42(2), 730-747. https://doi.org/10.1108/LHT-01-2023-0002

Lantu, D.C., Labdhagati, H., Bangun, Y.R., & Sumarli, F.D. (2023). The use of a flipped classroom and experiential learning in an undergraduate management course. International Journal of Educational Management, 37(1), 103-116. https://doi.org/10.1108/IJEM-05-2021-0189

Latorre-Cosculluela, C., Suárez, C., Quiroga, S., Sobradiel-Sierra, N., Lozano-Blasco, R., & Rodríguez-Martínez, A. (2021). Flipped classroom model before and during COVID-19: using technology to

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

develop 21st century skills. Interactive Technology and Smart Education, 18(2), 189-204. https://doi.org/10.1108/ITSE-08-2020-0137
Leão, P., Coelho, C., Campana, C., & Viotto, M.H. (2023). Flipped classroom goes sideways: reflections on active learning methodologies. Revista de Gestão, 30(2), 207-220. https://doi.org/10.1108/REGE-04-2021-0066
Ministry of Education. (2019). National Education Act (No. 4) B.E. 2019. Bangkok: Shipping and Parcel Printing Houses.
Ministry of Education. (2023). The Thirteenth National Socio-Economic Development Plan (2023-2027). Retrieved from http://www.bic.moe.go.th/images/stories/pdf/4-11-2565.pdf
Nachatar Singh, J.K., Nagpal, S., Inglis, S., & Jacob-John, J. (2019). International students' experiences in a flipped classroom environment: An Australian perspective. International Journal of Educational Management, 33(6), 1303-1315. https://doi.org/10.1108/IJEM-11-2018-0362
Pereira Bueno, R.L., Ribeiro Serra, F.A., & Scafuto, I.C. (2023). Executive perceptions of course and educator performance on flipped classroom. Education + Training, 65(8/9), 1023-1042. https://doi.org/10.1108/ET-08-2022-0337
Phakamach, P. (2023). Educational innovation: elements and mechanisms for the development of Thai educational institutions towards internationalization. Journal of Education and Innovative Learning, 3(2), 161-179.
Phakamach, P., Supap, S., Anukul, N., Onsampant, S., Wongsukha, S., & Sommartdejsakul. N. (2024a). The Effects of Education Quality System Management on the Development of Basic Education Institutions in Khon Kaen Province as an Educational Innovative Organisation. Asian Education and Learning Review, 2(2), 16-29. https://doi.org/10.14456/aelr.2024.7
Phakamach, P., Yoncheaun, J., Phomdee, R., Wongsukha, S., & Sommartdejsakul, N. (2024b). Development of Virtual Exchange-Learning Management System Platform Combined with Challenge-Based Learning on the Topic of Education Leadership and Disruption in the Digital Era. International Journal of Science Education and Teaching, 3(2), 51-66. https://doi.org/10.14456/ijset.2024.5
Ramírez-Montoya, M.-S., & Portuguez-Castro, M. (2024). Expanding horizons for the future with an open educational model for complex thinking: external and internal validation. On the Horizon, 32(1), 32-48. https://doi.org/10.1108/OTH-12-2023-0042
Şahin, Ş., & Kılıç, A. (2025). Comparison of face-to-face and online flipped learning: academic achievement, epistemological and pedagogical beliefs. Journal of Applied Research in Higher Education, 17(2), 563-577. https://doi.org/10.1108/JARHE-09-2023-0434
Samaila, K., & Al-Samarraie, H. (2024). Reinventing teaching pedagogy: the benefits of quiz-enhanced flipped classroom model on students' learning outcomes and engagement. Journal of Applied Research in Higher Education, 16(4), 1214-1227. https://doi.org/10.1108/JARHE-04-2023-0173
Sinlarat, P. (2020). The path to excellence in Thai education. RICE Journal of Creative Entrepreneurship and Management, 1(2), 60-75.
Smith, K.D. (2021). Is it face time or structure and accountability that matter? Moving from a Flipped to a Flipped/Hybrid Classroom. Journal of Applied Research in Higher Education, 13(2), 609-621. https://doi.org/10.1108/JARHE-08-2019-0229
Suwardika, G., Sopandi, A.T., Indrawan, I.P.O., & Masakazu, K. (2024). A flipped classroom with whiteboard animation and modules to enhance students' self-regulation, critical thinking and communication skills: a conceptual framework and its implementation. Asian Association of Open Universities Journal, 19(2), 135-152. https://doi.org/10.1108/AAOUJ-10-2023-0115
Tsortanidou, X., Daradoumis, T., & Barberá, E. (2019). Connecting moments of creativity, computational thinking, collaboration and new media literacy skills. Information and Learning Sciences, 120(11/12), 704-722. https://doi.org/10.1108/ILS-05-2019-0042
Weinhandl, R., Lavicza, Z., & Houghton, T. (2020). Mathematics and STEM teacher development for flipped education. Journal of Research in Innovative Teaching & Learning, 13(1), 3-25. https://doi.org/10.1108/JRIT-01-2020-0006
Zainuddin, Z., Haruna, H., Li, X., Zhang, Y., & Chu, S.K.W. (2019). A systematic review of flipped classroom empirical evidence from different fields: What are the gaps and future trends?. On the Horizon, 27(2), 72-86. https://doi.org/10.1108/OTH-09-2018-0027
Zainuddin, Z., & Perera, C.J. (2018). Supporting students' self-directed learning in the flipped classroom through the LMS TES blend space. On the Horizon, 26(4), 281-290. https://doi.org/10.1108/OTH-04-2017-0016

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

International Journal of Science Education and Teaching
Vol. 4, No. 2, pp. 141-157, May. – Aug. 2025
http://doi.org/10.14456/ijset.2025.10

Promoting Scientific Problem-Solving Skills of Grade-3 Students on the Topic of Electrical Energy Using a Problem-Based Learning Approach

Phatsarapron Sahakit[1], and Parnwadee Airlang [2*]
[1]*Phuket Rajabhat University, Phuket*
[1]*Phuket Rajabhat University, Phuket*
*Email: Phatsarapron.p@pkru.ac.th

Received: 13 Apr. 2025 Revised: 28 Aug. 2025 Accepted: 28 Aug. 2025

Abstract. This classroom action research aimed to enhance Grade-3 students' scientific problem-solving skills on the topic of electrical energy using a problem-based learning (PBL) approach. The participants were 28 students from a public school in Phuket Province, purposively selected because the researcher was also their classroom teacher. The intervention consisted of four PBL-aligned lesson plans. Research instruments included a 20-item three-answer choices test and four in-class activity sheets, each aligned with four domains of scientific problem-solving: identifying problems, analyzing problems, proposing solutions, and evaluating outcomes. Data were analyzed using both quantitative (descriptive statistics) and qualitative (content analysis) methods. Findings revealed a significant improvement in students' problem-solving skills, with post-test scores (M = 74.43%) exceeding pre-test scores (M = 60.53%). Qualitative data indicated increased proficiency in identifying relevant problems, applying reasoning, and evaluating solutions. The study highlights the effectiveness of the PBL model in fostering higher-order thinking and scientific reasoning in primary education. Implications are offered for instructional design, early science education, and curriculum reform in competency-based learning contexts.

Keywords: Scientific problem-solving; problem-based learning; primary education; electrical energy; action research

INTRODUCTION

In the 21st century, technological advancements have increasingly taken over roles traditionally performed by humans, rendering many conventional skills sets outdated. The pervasive integration of information and communication technology across all areas of life necessitates a transformation in the competencies required in the modern workforce (Dwyer et al., 2014; Hidayah et al., 2017). To succeed in this era, students must develop key 21st-century skills, including critical thinking and problem-solving, creativity and innovation, as well as collaboration and communication (Hosnan, 2014; Redhana, 2019). Therefore, educators must carefully select instructional models that align with the competencies demanded by the 21st-century learning environment.

Contemporary Thai education aims to develop individuals into well-rounded human beings across all dimensions, as outlined in the National Education Act of 1999 and its Amendment (No. 2) of 2002 (Office of the National Education Commission, 2002, p. 14), the 13th National Economic and Social Development Plan (2023–2027), and the education reform policy for the third decade (2019–2028). These policies share a common goal: to cultivate learners with advanced cognitive abilities such as analytical thinking, integrative thinking, synthetic thinking, problem-solving, and critical thinking. Additionally, they emphasize the ability to access and utilize technology, foster environmental awareness, promote public mindedness geared toward contributing to society,

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

encourage the creation of social good, and support harmonious coexistence within the community (Ministry of Education, 2008, p. 5).

Problem-based learning (PBL) is an instructional model grounded in constructivist learning theory, where learners construct new knowledge through engagement with real-world problems as the learning context. This approach enables students to develop analytical and problem-solving skills while simultaneously acquiring knowledge within their respective disciplines.

PBL is fundamentally a process-oriented method that emphasizes understanding and problem resolution. As a teaching strategy, it promotes self-directed learning by encouraging students to independently explore and confront problems. Through this process, learners are given opportunities to develop a range of thinking skills, including critical thinking, analytical thinking, synthetic thinking, and creative thinking.

From the management of science learning activities, it was observed that when students were presented with tasks involving real-life situations and current news for analysis, most of them struggled to identify key issues or understand the problems. They also faced difficulties in designing problem-solving processes. Scientific problem-solving skills are essential for living in the modern era. Therefore, the researcher aimed to enhance students' abilities in this area to support further learning in subsequent units and to enable the application of these skills across other subjects.

Based on the reasons and significance outlined above, the researcher is interested in developing the scientific problem-solving skills of Grade-3 students on the topic of electricity. It is believed that implementing a problem-based learning model is an effective instructional approach for fostering these skills. This approach encourages students to analyze real-life situations, which leads them to identify problems, propose solutions, and evaluate the outcomes of their problem-solving processes. Through this, students can demonstrate their understanding and ability to apply their knowledge effectively.

The present study distinguishes itself from previous research through its contextual grounding, methodological rigor, and contribution to early science education. While much of the existing literature on problem-based learning (PBL) in science education has centered on secondary or tertiary education contexts (e.g., Joseph & Melfei, 2019), this study focuses explicitly on Grade-3 primary school students in a public school in Phuket Province, Thailand. This localization of the research setting enables the investigation to directly respond to the learning needs and lived experiences of younger learners, particularly in the area of electrical energy—a topic embedded in students' everyday realities. This context-sensitive approach aligns with the call for curriculum development that is both culturally responsive and pedagogically sound (Dwyer, Hogan, & Stewart, 2017).

Methodologically, the study employs a classroom action research model based on Kemmis and McTaggart's (2008) four-cycle framework. Unlike traditional experimental studies that isolate variables under controlled conditions, the action research design allows for iterative refinement of instructional practices based on real-time feedback and reflective analysis. As such, it embodies the dual roles of the teacher as both practitioner and researcher, thereby bridging the gap between theory and practice in science education.

Furthermore, this research innovatively disaggregates scientific problem-solving into four distinct skill domains: (1) identifying the problem, (2) analyzing the problem, (3) proposing solutions, and (4) evaluating results. This detailed breakdown allows for more nuanced measurement of student learning than is typically found in studies that rely solely on summative assessments. By integrating both quantitative (pre- and post-tests) and qualitative (student activity sheets and observations) data, the study offers a comprehensive picture of student growth and highlights the developmental trajectory of problem-solving skills across instructional cycles.

In contrast to previous studies that often overlook the capacity of young learners to engage in complex inquiry, this study reveals that even early primary students can successfully develop scientific reasoning when guided through structured, real-world problems in a collaborative learning environment. As such, it offers both theoretical and practical insights into how PBL can be effectively adapted for younger age groups and embedded within localized curricular frameworks. This contribution is particularly valuable in advancing educational equity and improving science literacy at foundational levels.

In the 21st century, scientific problem-solving skills have become essential competencies for learners to navigate complex, real-world challenges. Early development of these skills in primary

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under [CC BY-NC-ND 4.0](https://creativecommons.org/licenses/by-nc-nd/4.0/).

education is critical, as it lays the foundation for higher-order thinking and lifelong learning. However, young students often struggle to identify, analyze, and resolve scientific problems in meaningful ways.

To address this gap, this study adopts a Problem-Based Learning (PBL) approach grounded in constructivist theory. PBL encourages learners to engage with authentic, real-life problems, fostering analytical thinking, creativity, and self-directed learning. This instructional model aligns with national education policies in Thailand, which emphasize competency-based education and 21st-century skills.

Focusing on Grade-3 students in Phuket Province, this research aims to enhance students' scientific problem-solving skills through a localized and culturally responsive science lesson on electrical energy—a topic embedded in everyday experiences. By employing a classroom action research model, the study not only supports iterative improvement of instructional practices but also contributes to the discourse on early science education and equity.

RESEARCH OBJECTIVES

To develop the scientific problem-solving skills of Grade-3 students on the topic of electrical energy through the implementation of a problem-based learning model.

CONCEPTUAL FRAMEWORK

This study is grounded in the constructivist theory of learning, which posits that students actively construct their own understanding and knowledge through experiences and reflection (Piaget, 1950; Vygotsky, 1978). Based on this theoretical perspective, the Problem-Based Learning (PBL) approach is employed to serve as the instructional foundation for promoting scientific problem-solving skills among Grade-3 students.

1. Problem-Based Learning (PBL)

PBL is an instructional model that centers on real-world problems as the context for learning. Learners engage with ill-structured problems that do not have straightforward solutions, which encourages them to think critically, collaborate with peers, explore relevant information, and apply knowledge to formulate and evaluate solutions (Barrows & Tamblyn, 1980). In this study, the PBL model consists of the following key stages:

Engagement with a real-world problem: Students encounter issues related to electrical energy (e.g., energy conservation, energy sources).

Investigation and exploration: Students analyze the problem by connecting prior knowledge with new information.

Solution proposal: Students formulate possible solutions based on scientific reasoning.

Evaluation and reflection: Students evaluate the effectiveness of the proposed solutions and reflect on the learning process.

2. Scientific Problem-Solving Skills

Scientific problem-solving refers to a set of cognitive processes that students use to address scientific questions or real-life problems. In this study, the skills are categorized into four components:

Problem Identification: Recognizing and clearly defining the problem.

Problem Analysis: Understanding the cause-effect relationships and identifying relevant information.

Proposing Solutions: Suggesting plausible and evidence-based methods to resolve the problem.

Evaluating Solutions: Assessing the validity and effectiveness of the solution based on scientific principles.

3. Interrelationship Between PBL and Scientific Problem-Solving Skills

The PBL model aligns with and supports the development of scientific problem-solving skills through the following mechanisms:

PBL promotes active learning, which is essential for students to internalize and apply problem-solving strategies.

The iterative process of inquiry embedded in PBL mirrors the stages of scientific problem-solving.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

By working collaboratively and engaging in dialogue, students refine their reasoning and deepen their understanding of scientific content.

The real-world problems used in PBL provide authentic contexts that enhance the relevance and transferability of problem-solving skills.

Thus, in this study, the PBL approach is hypothesized to positively influence students' scientific problem-solving skills, particularly in the context of learning about electrical energy. The conceptual framework is illustrated in Figure 1.

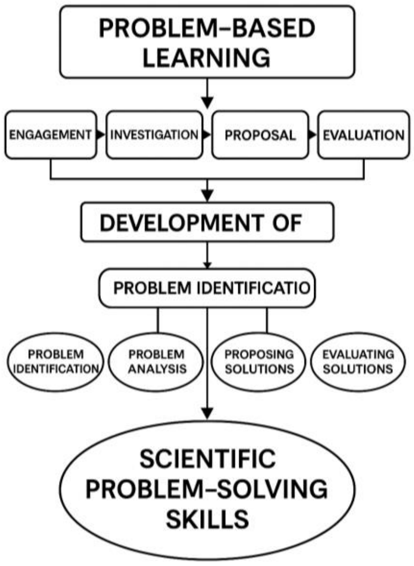


Figure 1. conceptual framework

METHODOLOGY

This research employs a classroom action research design, in which the researcher, acting as the classroom teacher, conducts the study. It adopts a mixed-methods approach, with quantitative data collection and analysis as the primary method, and qualitative data collection and analysis as a secondary method integrated throughout the research process.

The study follows Kemmis and McTaggart’s (2008, p. 278) four-stage action research cycle, which includes:

(1)Planning Stage: The researcher investigates learning management problems by reviewing relevant literature and prior research. This stage also involves assessing students' scientific problem-solving skills using a skill test focused on the topic of electrical energy. The results inform the design of learning activities based on the problem-based learning model.

(2) Action Stage: The researcher implements the problem-based learning lesson plans that were developed during the planning stage.

(3) Observation Stage: The researcher observes students' behaviors during the instructional process and collects data using research tools, including activity sheets related to the topic of electrical energy and the scientific problem-solving skill test.

(4) Reflection Stage: Data from both quantitative and qualitative instruments are analyzed to guide the improvement and refinement of the lesson plans for the next cycle.

This process continues through four full cycles. After the completion of all instructional plans, students’ scientific problem-solving skills are assessed again using the same test. The researcher then synthesizes the research process, as illustrated in **Figure 2**.

Participants

Twenty-eight Grade-3 students from a school in Phuket Province were selected through purposive sampling. As the researcher also serves as the classroom teacher, issues related to students’ lack of problem-solving skills were identified based on classroom evidence such as their responses

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

to questions derived from media and innovations used during instruction. It was observed that the students were unable to effectively identify problems or design appropriate solutions.

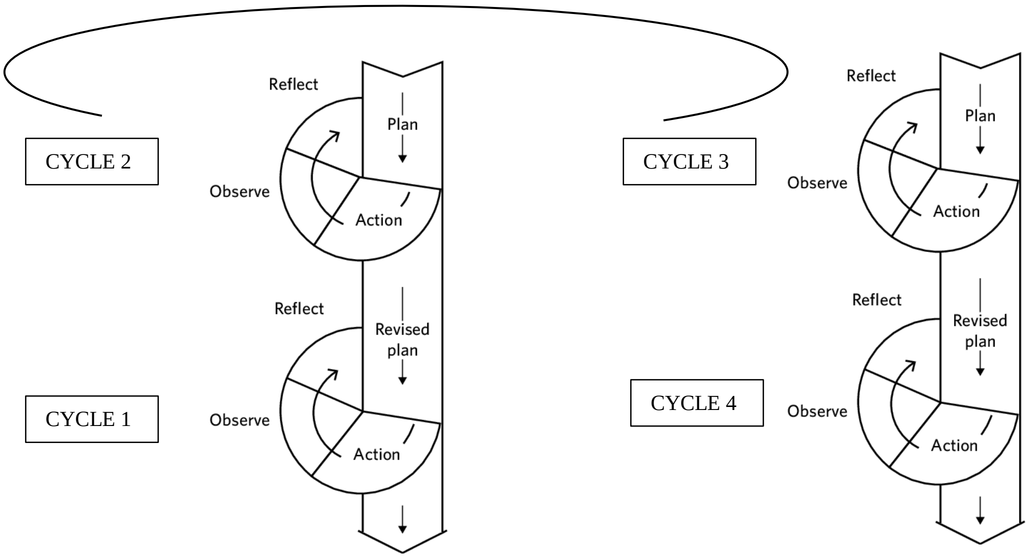


Figure 2. The steps of the action research process.

Research Tools

1. Lesson Plans: A total of four learning management plans were implemented over eight hours, as follows:

1.1 Lesson Plan 1: *Converting One Form of Energy to Another* 2 hours.

1.2 Lesson Plan 2: *Electricity Production and Energy Sources for Electricity Production* 2 hours.

1.3 Lesson Plan 3: *Benefits and Harms of Electricity* – 2 hours.

1.4 Lesson Plan 4: *How to Use Electricity Economically and Safely* 2 hours.

2. Scientific Problem-Solving Skill Test: The test covered four main topics aligned with the lesson plans:

2.1 Converting one form of energy to another.

2.2 Electricity production and energy sources for electricity production.

2.3 Benefits and harms of electricity.

2.4 How to use electricity economically and safely.

3. Test Format: The scientific problem-solving skill test consisted of 20 multiple-choice questions (three options per item) and was administered as both a pre-test and a post-test.

Instrument Quality and Validation Procedures

To ensure the quality, accuracy, and credibility of the assessment instruments used in this study, the following procedures were employed to examine both their validity and reliability.

1. Instrument Development: The research instruments consisted of (1) a 20-item three answer choices test on scientific problem-solving skills, and (2) in-class activity sheets. Both instruments were designed to assess students' abilities across four domains: identifying problems, analyzing problems, proposing solutions, and evaluating outcomes. The content of the items was based on four key subtopics related to electrical energy, corresponding to the instructional units implemented in the classroom.

The 20-item multiple-choice test on scientific problem-solving skills was developed to assess students' cognitive processes in four major domains: identifying problems, analyzing problems, proposing solutions, and evaluating outcomes. These domains align with established frameworks for scientific reasoning and problem-solving, such as those proposed by Jonassen (2000), Mayer and Wittrock (2006), and OECD (2019) in the context of PISA scientific literacy.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

The item development process followed these steps:

(1) Content Specification: The items were constructed based on four key subtopics in electrical energy aligned with the instructional content delivered in the classroom.

(2) Cognitive Process Alignment: Each item was designed to reflect a specific stage of the scientific problem-solving cycle (Bybee, 2002; Huitt, 1992).

(3) Expert Review: A panel of three science education experts reviewed the items for content validity, clarity, and alignment with the target skills.

(4) Pilot Testing: The instrument was piloted with 30 students not involved in the main study to assess item difficulty, discrimination index, and reliability.

(5) Reliability Analysis: Cronbach's alpha coefficient for the overall instrument was calculated to ensure internal consistency, targeting $\alpha \geq 0.70$.

According to Mayer and Wittrock (2006), effective scientific problem-solving assessments should elicit students' abilities to recognize a problem, reason through causes and consequences, generate possible solutions, and evaluate the appropriateness of those solutions. The design of the present instrument adheres to this framework, as shown in the table below.

Instrument Quality and Validation Procedures

The 20-item multiple-choice test was developed to assess students' scientific problem-solving skills, grounded in established theoretical frameworks (Table 1). The process was rigorous and included multiple phases to ensure content validity, clarity, alignment, and reliability.

Literature Reviews Informing the Test Development

1) Jonassen (2000), Mayer & Wittrock (2006), and OECD (2019): These scholars propose frameworks that define scientific problem-solving as a cognitive process involving recognizing problems, analyzing data, generating solutions, and evaluating outcomes.

2) Bybee (2002); Huitt (1992): Their work on scientific reasoning cycles guided the alignment of each test item with specific stages in the problem-solving process.

3) Mayer and Wittrock (2006): Emphasized that effective problem-solving assessments should involve:

3.1) Identifying a problem.
3.2) Reasoning through causes and consequences.
3.3) Generating potential solutions.
3.4) Evaluating the appropriateness of solutions.

These sources validated the inclusion of four major domains in the instrument: (1) Identifying Problems, (2) Analyzing Problemsม (3) Proposing Solutionsม and (4) Evaluating Outcomes.

Table 1: Mapping of 20 Multiple-Choice Items to Scientific Problem-Solving Skills

Item No.	Subtopic in Electrical Energy	Target Skill Domain	Problem-Solving Skill Represented
1–5	Electric current and circuits	Identifying problems	Recognizing phenomena that signal a malfunction or inconsistency
6–10	Electrical resistance	Analyzing problems	Interpreting diagrams, data, and cause-effect relationships
11–15	Power and energy consumption	Proposing solutions	Suggesting ways to reduce energy use or correct system errors
16–20	Safety and practical applications	Evaluating outcomes	Judging the effectiveness or safety of proposed electrical setups

Development Process Summary:

1) Content Specification: Items were based on four key subtopics in electrical energy taught in class.

2) Cognitive Process Alignment: Each item matched a stage in the scientific problem-solving cycle.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

3) Expert Review: Panel of science education experts ensured validity and alignment.

4) Pilot Testing: Conducted with 30 students to measure difficulty, discrimination, and reliability.

5) Reliability Analysis: Achieved Cronbach's alpha ≥ 0.70, ensuring internal consistency.

This structured alignment ensured that the assessment was not only content-valid but also reflective of meaningful cognitive and scientific processes. The integration of problem-solving components based on literature enhances the instrument's utility in diagnosing students' strengths and gaps in scientific reasoning (OECD, 2019; Jonassen, 2000).

How the Researcher Might Have Designed the Analytic Scoring Rubrics

Although not explicitly detailed in the image, a logical design of analytic scoring rubrics for scientific problem-solving skills would follow the four domains referenced in the study: 1) Identifying Problems 2) Analyzing Problems 3) Proposing Solutions 4)Evaluating Outcomes

The researcher would likely create rubric dimensions aligned with each of these cognitive domains, incorporating performance levels (e.g., 0 = No attempt, 1 = Emerging, 2 = Developing, 3 = Proficient, 4 = Advanced).

Steps in Rubric Development (Inferred from Educational Measurement Literature):

1) *Define Constructs*. Based on Jonassen (2000), Mayer & Wittrock (2006), and Bybee (2002), clearly define the cognitive skill for each rubric category.

2) *Determine Performance Levels*. Establish 3–5 levels of achievement per skill (e.g., "Incorrect," "Partial," "Complete and Reasoned").

3) *Align Criteria with the Scientific Problem-Solving Cycle*. As per Bybee's 5E model (Engage, Explore, Explain, Elaborate, Evaluate), ensure rubric items evaluate reasoning, evidence use, and clarity.

4) *Expert Review*. As mentioned in the image, expert validation is a critical step (e.g., three science education experts reviewed test content—likely true for rubrics too).

5) *Pilot Testing and Revision*. Use pilot student responses to calibrate the rubric, revise criteria, and ensure inter-rater reliability.

As illustrated in **Table 2**, the rubric dimensions are directly aligned with the four cognitive domains of scientific problem-solving. For example, the *Identifying Problems* domain emphasizes students' ability to accurately recognize the core issue, consistent with Jonassen's (2000) framework on problem representation. The *Analyzing Problems* domain highlights interpretation of data and causal reasoning, which reflects the importance of analytical thinking in Mayer and Wittrock's (2006) model. Similarly, the *Proposing Solutions* domain ensures that students generate feasible and context-relevant responses, echoing Bybee's (2002) emphasis on authentic inquiry and OECD's (2019) focus on real-world problem solving. Finally, the *Evaluating Outcomes* domain underscores the critical appraisal of solution safety, effectiveness, and efficiency, as supported by Mayer and Wittrock (2006). Thus, Table 2 not only operationalizes the abstract constructs defined in the rubric design steps but also grounds them in established literature, ensuring that the scoring process is both theoretically robust and pedagogically meaningful.

Table 2: Example of Possible Rubric Dimensions.

Skill Domain	Criteria Example	Reference
Identifying Problems	Accurately identifies the core scientific issue or inconsistency	Jonassen (2000)
Analyzing Problems	Interprets data/diagrams correctly; explains cause-effect clearly	Huitt (1992), Mayer & Wittrock (2006)
Proposing Solutions	Suggests feasible, science-based, and context-relevant solutions	Bybee (2002), OECD (2019)
Evaluating Outcomes	Critically evaluates solution safety, effectiveness, and efficiency	Mayer & Wittrock (2006)

2. Content Validity: To establish content validity, the initial draft of the test and activity sheets was reviewed by three experts in the fields of science education and educational assessment.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Each item was evaluated for alignment with the instructional objectives, clarity of language, and relevance to scientific problem-solving skills. The Item-Objective Congruence (IOC) index was calculated, and items receiving an IOC score of 0.67 or above were retained. Items with lower scores were revised or removed.

3. Pilot Testing: The revised version of the test was then pilot-tested with a group of 15 Grade-3 students who shared similar characteristics with the target population but were not part of the main study. This pilot aimed to ensure that all items were understandable, the test length was appropriate, and the wording was age-appropriate.

4. Item Analysis: Data from the pilot test were analyzed to evaluate item difficulty and discrimination. Items were retained if their P-values (difficulty index) fell within the recommended range (0.20–0.80), and their discrimination indices (D) were at least 0.20. Items not meeting these criteria were revised or excluded to enhance the overall quality of the instrument.

5. Reliability Estimation: The internal consistency reliability of the test was computed using Kuder-Richardson Formula 20 (KR-20), suitable for dichotomous items. A KR-20 value of 0.70 or higher was considered acceptable, indicating that the test was sufficiently reliable for measuring student learning outcomes.

6. Scoring Rubrics for Qualitative Data: For the in-class activity sheets, analytic scoring rubrics were developed to assess students' performance in each domain of scientific problem-solving. The rubrics were subjected to expert validation to ensure clarity and alignment with theoretical constructs. Two independent raters were trained to apply the rubric to a sample of student responses, and inter-rater reliability was calculated using Cohen's Kappa to confirm consistency between scorers.

Data Collection

The researcher collected data according to the following steps:

(1) The researcher administered the scientific problem-solving skill test on the topic of electrical energy before the lesson to gather baseline data from the students. The test was scored and recorded for accuracy.

(2) The researcher conducted learning activities using the problem-based learning approach and collected data on students' scientific problem-solving skills that emerged during the lesson, over the course of four sessions.

(3) The researcher administered the same scientific problem-solving skill test on electrical energy after the lesson, then checked and recorded the students' scores.

(4) The learning outcomes were analyzed using both quantitative and qualitative methods: 1) Problem identification, 2) Problem analysis,) Proposal of problem-solving methods, and 4) Verification of problem-solving results.

Data Analysis

Data analysis in this research was divided according to the nature of the data: quantitative and qualitative, as follows:

(1) Quantitative data included evaluation scores from activity sheets based on the learning activity plans, as well as scores from students' scientific problem-solving skill tests. The data were analyzed using percentage calculations.

(2) Qualitative data consisted of students' responses from activity sheets, which were grouped to categorize their scientific problem-solving skills into four areas: 1) Problem identification, 2) Problem analysis, 3) Proposal of problem-solving methods, and 4) Verification of problem-solving results.

Students' responses were analyzed and grouped according to the components of problem-solving skills, and their levels of development were reported in percentages.

In this study, data were analyzed using both quantitative and qualitative approaches to provide a comprehensive understanding of students' development in scientific problem-solving skills.

1. Quantitative Data Analysisฃ

Quantitative data were derived from two sources:

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

- Scores obtained from the scientific problem-solving skill test (administered as a pre-test and post-test).
- Scoring results from student activity sheets, which corresponded to each of the four lesson plans.

The following steps were undertaken for the quantitative analysis:

1. Scoring: Students' responses to multiple-choice items in the pre- and post-tests were scored dichotomously (1 point for a correct answer, 0 for an incorrect answer). Each test comprised *20* items, yielding a maximum possible score of 20.

Percentage Calculation: The raw scores were converted into percentages to facilitate interpretation and comparison between pre-test and post-test performance. These percentages reflected the extent of students' improvement in scientific problem-solving skills.

Descriptive Statistics: Data were summarized using descriptive statistics, including mean scores and percentage of correct responses, to highlight the overall learning gains and identify areas of strength or weakness.

Skill-Based Categorization: Test items were mapped to four specific skill domains problem identification, problem analysis, solution proposal, and result evaluation allowing for domain-specific quantitative analysis of student performance.

The analytic scoring rubrics used in this study were developed to evaluate students' performance on in-class activity sheets across four core domains of scientific problem-solving: identifying problems, analyzing problems, proposing solutions, and evaluating outcomes. The development of the rubrics followed established principles from assessment literature emphasizing clarity, objectivity, and alignment with learning goals (Brookhart, 2013; Moskal, 2000).

The steps in designing the analytic rubric were:

(1) Domain Specification: Each rubric dimension reflected a component of problem-solving skills (e.g., identifying variables, reasoning through evidence, selecting appropriate solutions).

(2) Level Descriptors: Performance levels were divided into four tiers: **Beginning (1)**, **Developing (2)**, **Proficient (3***)* Each level was described with specific behavioral indicators to ensure consistency in scoring.

(3) Content and Cognitive Alignment: Rubric criteria were mapped directly to the learning outcomes and the types of cognitive tasks expected in each activity. This approach is consistent with recommendations by Nitko & Brookhart (2014) that rubrics should align with instructional objectives and promote valid inferences about learning.

(4) Expert Validation: Three experts in science education reviewed the rubric for content validity, ensuring that each criterion was clear, observable, and developmentally appropriate.

(5) Pilot Application and Revision: The rubric was trialed with a sample of student responses. Inter-rater reliability was calculated using Cohen's Kappa, and necessary revisions were made based on discrepancies and expert feedback.

This method reflects a **constructive alignment** approach (Biggs & Tang, 2011), ensuring coherence between learning outcomes, instruction, and assessment.

2. Qualitative Data Analysis: Qualitative data were drawn from students' open-ended responses on activity sheets completed during the learning process. These responses were analyzed using the following procedures:

Data Coding: Student responses were first categorized according to the four scientific problem-solving components: (1) Identifying the problem, (2) Analyzing the problem, (3) Proposing solutions, and (4) Verifying the results.

Criteria for Classifying Student Responses into Problem-Based Learning Skill Domains

To evaluate students' scientific problem-solving skills, student responses from the activity sheets were classified into four core domains of problem-based learning: (1) Problem Identification, (2) Problem Analysis, (3) Solution Proposal, and (4) Result Evaluation. Each domain was assessed using a structured rubric that categorized student responses into three developmental levels **Beginning**, **Developing**, and **Proficient** based on clearly defined criteria.

The rubric development process described above is concretely operationalized in **Table 2** and further elaborated in **Table 3**. While Table 2 presents the broader rubric dimensions across four

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

core domains of scientific problem-solving (identifying problems, analyzing problems, proposing solutions, and evaluating outcomes), Table 3 provides detailed performance levels and criteria within each domain. For example, in the *Problem Identification* domain, Table 2 outlines the importance of recognizing the core scientific issue (Jonassen, 2000), and Table 3 expands this into observable levels ranging from "fails to identify the problem" (Beginning) to "clearly identifies with accurate reference to context or content" (Proficient). Similarly, the domains of problem analysis, solution proposal, and result evaluation in Table 2 are specified in Table 3 with progressive achievement descriptors (Beginning–Developing–Proficient). Together, these tables illustrate how abstract rubric dimensions (Table 2) are systematically translated into measurable performance indicators (Table 3), ensuring validity, clarity, and consistency in assessing scientific problem-solving skills.

Table 3: Rubric for Assessing Levels of Scientific Problem-Solving Competence

Level	Criteria
1. Problem Identification	
Proficient	Clearly identifies the problem, with accurate reference to real-life context or scientific content.
Developing	Identifies a general issue or partial aspect of the problem but lacks clarity or precision.
Beginning	Fails to identify the problem or presents unrelated or vague information.
2. Problem Analysis	
Proficient	Analyzes the problem by identifying relevant causes, factors, or scientific concepts with logical reasoning.
Developing	Provides some relevant analysis but lacks depth, completeness, or contains partial misconceptions.
Beginning	Provides little or no analysis; shows misunderstanding or random ideas unrelated to the problem.
3. Solution Proposal	
Proficient	Proposes a feasible, clearly explained, and scientifically valid solution.
Developing	Suggests a possible solution, though it may lack full explanation or contain minor scientific inaccuracies.
Beginning	Offers an implausible or unscientific solution, or fails to propose a solution at all.
4. Result Evaluation	
Proficient	Evaluates the effectiveness of the proposed solution with evidence, reasoning, or real-world applicability.
Developing	Attempts an evaluation but lacks justification or shows limited connection to the problem.
Beginning	Does not evaluate the result or provides irrelevant or unclear comments.

This rubric was applied consistently to each student's responses across all learning sessions. Two trained raters independently scored the responses, and inter-rater reliability was established using Cohen's Kappa to ensure consistency. The frequency of students falling into each level per domain was then converted into percentages for reporting in the results section.

Thematic Grouping: Within each category, responses were grouped by theme to determine common patterns and variations in student thinking. This process allowed researchers to identify how students approached each stage of the problem-solving process.

Developmental Level Classification: Each student's response in each domain was evaluated against a rubric or criteria developed to determine the level of proficiency (e.g., beginning, developing, proficient). These levels were then quantified into percentages, providing an overview of student progress and learning distribution.

Triangulation: The qualitative findings from the activity sheets were compared and cross-referenced with quantitative test results to enhance the reliability and validity of the interpretations.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

RESULTS AND DISCUSSION

This research aimed to develop the scientific problem-solving skills of Grade-3 students on the topic of electrical energy using a problem-based learning model, implemented before, during, and after instruction. Data were collected through a science problem-solving skill test, and the results were analyzed accordingly. The researcher presents the data analysis results as follows:

Part 1: Analysis of the scientific problem-solving skill activity sheets

Part 2: Analysis of the scientific problem-solving skill test results before and after instruction

Part 3: Students' scientific problem-solving abilities before, during, and after instruction using the problem-based learning model on the topic of electrical energy

Chapter 1: Analysis of the scientific problem-solving skill activity sheets

Chapter 1 presents the analysis of students' scientific problem-solving skills through their responses to four structured lesson plans. Each lesson plan was designed to engage students in different contexts of energy and electricity, allowing the researcher to observe how students performed across the four core dimensions of problem-solving: *problem identification, problem analysis, proposing solutions, and verifying results.* The findings reveal that students' performance varied across lessons. For instance, in Lesson Plan 1, many students demonstrated difficulties in clearly identifying the problem and proposing solutions relevant to the context, which indicates a Developing or Beginning level of performance. In contrast, Lesson Plans 2–4 show progressive improvement, as students were increasingly able to connect the problems with real-life contexts, propose scientifically valid and practical solutions, and verify the results effectively.

Overall, Chapter 1 highlights not only the challenges students face in early attempts at scientific problem-solving but also the evidence of growth when learning activities are scaffolded. This provides a strong rationale for using analytic rubrics (as outlined in Table 1) to capture performance differences across domains and levels, ensuring that assessment reflects both strengths and areas for further development.

As shown in **Table 4**, the grouping of students' answers across the four lesson plans provides clear evidence of how their scientific problem-solving skills develop in authentic learning contexts. In Lesson Plan 1, most responses reflect difficulties in both problem identification and solution proposal, indicating that students struggled to apply scientific reasoning to the given situation. However, from Lesson Plan 2 onward, students demonstrated greater accuracy in identifying core issues, analyzing problems in relation to real-life contexts, and proposing feasible solutions, such as renewable energy sources. Lesson Plans 3 and 4 further highlight students' progression toward proficiency, with many providing clear, context-relevant solutions and verifiable outcomes.

This pattern of responses illustrates the usefulness of the rubric dimensions (problem identification, problem analysis, solution proposal, and result evaluation) in capturing both strengths and weaknesses. Table 4 thus not only summarizes students' actual performance but also confirms that the analytic rubric framework is capable of differentiating between varying levels of competency. In this way, the table bridges theoretical constructs of problem-solving skills with practical classroom evidence, offering insights for refining instructional design and assessment practices.

As shown in Table 5, the summary of student performance across lesson plans provides a holistic picture of how their problem-solving skills evolved throughout the activities. Lesson 1 (*Energy Conversion*) reveals that students struggled particularly with *problem analysis, solution proposal,* and *result evaluation,* where most responses remained at the *Beginning* level. This suggests that students initially lacked the ability to apply scientific reasoning to contextual problems.

However, in Lessons 2–4, students consistently reached the *Proficient* level across all four domains. This indicates substantial improvement, as they were able to accurately identify problems, analyze them with logical reasoning, propose scientifically valid and context-relevant solutions, and verify results effectively. These findings confirm the progression already observed in Tables 3 and 4, where students moved from vague or inconsistent responses to increasingly accurate and scientifically grounded solutions.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Table 4: The results of grouping students' answers for all 4 activities.

Lesson Plan	Answer
Lesson Plan 1: *Converting One Form of Energy to Another*	(1) Problem identification *"Partially stated problem: Matter cannot change energy into other forms."* (2) Problem analysis *"Unable to analyze the cause of the problem: The student cannot determine whether the issue lies in matter being unable to convert energy or does not provide an answer at all."* (3) Proposal of problem-solving methods *"The design is not consistent with the issue: A separation process is written that is not relevant to the given situation."* (4) Verification of problem-solving results *"Check for inconsistent results: Provides a general description of substance changes that does not align with the given situation—for example, stating that substances can change in many forms depending on various factors."*
Lesson Plan 2: *Electricity Production and Energy Sources for Electricity Production*	(1) Problem identification *"Identifies 80% of the issues consistent with the situation: Recognizes that electricity is produced from natural energy sources and acknowledges that there are various sources of production."* (2) Problem analysis *"Analyzes problems in line with the situation: Connects the problem to related information, such as energy shortages and the depletion of energy production, leading to the need to find alternative natural energy sources."* (3) Proposal of problem-solving methods *"Proposes an approach consistent with the problem situation**:** Designs a method to test renewable energy sources, such as wind and sunlight, which have low production costs."* (4) Verification of problem-solving results *"The designed approach can be verified"*
Lesson Plan 3: *Benefits and Harms of Electricity*	(1) Problem identification *"Correctly identifies the problem**:** Students misuse electrical appliances and do not practice energy conservation."* (2) Problem analysis *"Shows the relationship through issue analysis: Not unplugging electrical appliances leads to excessive electricity consumption, despite electricity being essential for daily life."* (3) Proposal of problem-solving methods *"Provides clear solutions: Suggests actions for environmental conservation, such as unplugging power cords after use and using electricity only when necessary."* (4) Verification of problem-solving results *"The designed approach can be verified"*
Lesson Plan 4: *How to Use Electricity Economically and Safely*	(1) Problem identification *"Clearly identifies the issue: Raises students' awareness about electricity usage."* (2) Problem analysis *"Analyzes problems in line with the situation: Connects the problem to related information, such as energy shortages and the depletion of energy production, leading to the need to find alternative natural energy sources."* (3) Proposal of problem-solving methods *"Proposes an approach consistent with the problem situation**:** Designs a method to test renewable energy sources, such as wind and sunlight, which have low production costs."* (4) Verification of problem-solving results *"The designed approach can be verified"*

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

In this way, Table 5 not only synthesizes the performance trends but also validates the usefulness of the rubric framework (outlined in Table 2 and Table 3). It demonstrates how structured learning and repeated practice enabled students to progress from *Developing/Beginning* toward *Proficient* levels in scientific problem-solving, thereby highlighting the effectiveness of the instructional design.

Table 5: Student Problem-Solving Skill Levels by Lesson Plan.

Lesson Plan	Problem Identification	Problem Analysis	Solution Proposal	Result Evaluation
Lesson 1: Energy Conversion	Developing	Beginning	Beginning	Beginning
Lesson 2: Electricity Production	Proficient	Proficient	Proficient	Proficient
Lesson 3: Benefits & Harms	Proficient	Proficient	Proficient	Proficient
Lesson 4: Economic & Safe Use	Proficient	Proficient	Proficient	Proficient

The qualitative data, derived from student responses on activity sheets, revealed meaningful insights into the development of scientific problem-solving skills among Grade-3 students. The analysis focused on four key domains: problem identification, problem analysis, solution proposal, and result evaluation.

Overall, the findings demonstrated progressive growth in students' problem-solving abilities as they engaged in problem-based learning activities. In the initial lesson on energy conversion, most students exhibited limited conceptual understanding, as evidenced by vague or incorrect responses in all four skill domains. Their difficulty in identifying the problem accurately and proposing relevant solutions indicated a foundational level of scientific reasoning.

However, in subsequent lessons particularly those focused on electricity production, its benefits and harms, and safe usage practices students showed significant improvement. Their responses reflected an increased ability to Identify relevant problems grounded in real-life scenarios,Analyze issues logically by connecting them with prior knowledge and contextual factors, Propose feasible and scientifically valid solutions, and Evaluate the effectiveness of solutions with clear reasoning.

These findings suggest that the iterative implementation of problem-based learning enabled students to gradually internalize scientific inquiry processes. Additionally, the integration of real-world issues enhanced students' motivation and contextual understanding, leading to more thoughtful and structured problem-solving approaches.

The analysis also confirmed that even young learners, when guided through appropriately designed instructional strategies, can successfully develop complex reasoning and problem-solving skills. This highlights the pedagogical value of applying qualitative assessments to uncover nuanced dimensions of learning that standardized tests alone may overlook.

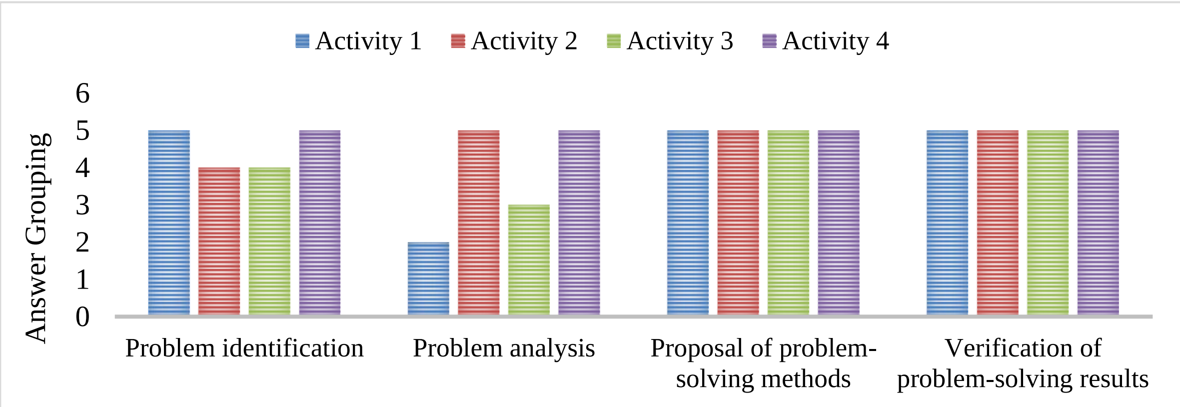


Figure 2. Results from grouping students' responses across all four activities.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

From Figure 2, it can be observed that, in terms of problem identification, students were able to identify the problems presented in each activity as designed by the teacher. However, in the area of problem analysis, the initial part of the chart shows a low performance level, indicating that students initially struggled to analyze the problems. As the activities progressed, by Activity 4, the chart shows a notable increase, suggesting that students improved their ability to analyze problems. In the aspects of proposing solution methods and evaluating the results, the chart indicates that all groups of students were able to perform these steps effectively.

Chapter 2: Analysis of Pre-Test and Post-Test Results on Scientific Problem-Solving Skills

Chapter 2 presents the analysis of pre-test and post-test results to evaluate the development of Grade-3 students' scientific problem-solving skills in the topic of electrical energy through a problem-based learning (PBL) approach. As indicated in Table 2, the mean score of students increased from 24.21 (S.D. = 2.28) on the pre-test to 29.79 (S.D. = 3.02) on the post-test, reflecting a clear improvement in performance following the instructional intervention.

When disaggregated into the four dimensions of problem-solving skills (problem identification, problem analysis, proposing solutions, and evaluating solutions), Table 3 shows that students initially demonstrated only moderate levels of ability (ranging from 57.14% to 64.64%). After instruction, however, their performance improved substantially, reaching high levels across all domains, with the highest gains observed in solution evaluation (80%).

Further evidence is provided in Table 4, which traces students' progress before, during, and after the lesson plans. The results demonstrate a steady increase in problem-solving proficiency, beginning with 60.53% at the pre-test and rising to 84.50% by the post-test. Notably, after each successive lesson plan, students showed consistent growth: 80% after Lesson 1, 78% after Lesson 2, 82% after Lesson 3, and 84% after Lesson 4. This progression underscores the effectiveness of the PBL model in scaffolding students' learning, enabling them to move from a moderate to a high level of problem-solving competence.

2.1 The pre-test and post-test scores of Grade-3 primary school students on the topic of electrical energy, taught using the problem-based learning model, are presented in Table 2.

Table 2: Displays the comparison of students' pre-test and post-test scores in scientific problem-solving skills.

Test	N	Maximum score	$\bar{x}$	S.D
Pre-test	28	40	24.21	2.28
Pos-test	28	40	29.79	3.02

From Table 13, it is shown that the pre-test scores of Grade-3 students on scientific problem-solving skills in the topic of electrical energy, using a problem-based learning approach, had a mean score ($\bar{x}$) of 24.21 (S.D. = 2.28). The post-test scores had a higher mean score ($\bar{x}$) of 29.79 (S.D. = 3.02).

2.2 The pre-test and post-test scores of scientific problem-solving skills among Grade-3 students on the topic of electrical energy, taught using a problem-based learning approach, can be categorized into four areas of scientific problem-solving skills: 1) Problem identification, 2) Problem analysis, 3) Proposing problem-solving methods, and (4) Evaluating the results of problem-solving.

Table 3: Presents the pre-test and post-test scores for each of these skill areas.

Problem-solving skills	N=28	
	Pre-test	**Pos-test**
(1) Problem identification	58.21	71.01
(2) Problem analysis	57.14	71.01
(3) Proposing problem-solving methods	62.14	75.71
(4) Evaluating the results of problem-solving	64.64	80
Total score of the student	**60.53**	**74.43**

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Scientific problem-solving ability on the topic of electrical energy revealed that before instruction using the problem-based learning model, most Grade-3 students demonstrated a moderate level of scientific problem-solving ability, accounting for 60.53%. This can be divided into four areas:

(1) Problem Identification – Most students demonstrated a moderate level, 58.21%
(2) Problem Analysis – Most students demonstrated a moderate level, 57.14%
(3) Proposing Solutions – Most students demonstrated a moderate level, 62.14%
(4) Evaluating Solutions – Most students demonstrated a moderate level, 64.64%

After instruction using the problem-based learning model, most students showed a high level of scientific problem-solving ability, at 74.43%. Specifically:

(1) Problem Identification – High level, 71.01%
(2) Problem Analysis – High level, 71.01%
(3) Proposing Solutions – High level, 75.71%
(4) Evaluating Solutions – High level, 80%

Table 4: Scientific Problem-Solving Ability of Students Before, During, and After Learning.

Problem-solving skills	**N=28**					
	Pre-Test	**Lesson Plan 1**	**Lesson Plan 2**	**Lesson Plan 3**	**Lesson Plan 4**	**Post-Test**
(1) Problem identification	58.21	100	60	90	80	71.01
(2) Problem analysis	57.14	30	80	50	60	71.01
(3) Proposing problem-solving methods	62.14	80	66.67	80	86.67	75.71
(4) Evaluating the results of problem-solving	64.64	100	100	100	100	80
Total score of the student	**60.53**	**80**	**78**	**82**	**84**	**84.50**

Before the instructional intervention, most students demonstrated a moderate level of scientific problem-solving ability, accounting for 60.53%. After the implementation of the problem-based learning approach, students showed improved scientific problem-solving skills, with 74.43% of students achieving a high level of ability.

This finding is consistent with the analysis of students' responses in the activity sheets after each lesson plan. It was found that:

(1) After Lesson Plan 1, most students demonstrated a high level of scientific problem-solving ability at 80%
(2) After Lesson Plan 2, the percentage was 78%
(3) After Lesson Plan 3, the percentage increased to 82%
(4) After Lesson Plan 4, the percentage further rose to 84%

CONCLUSION AND IMPLICATIONS

This study investigated the effectiveness of a problem-based learning (PBL) approach in promoting scientific problem-solving skills among Grade-3 students, with a focus on the topic of electrical energy. The findings based on both quantitative test scores and qualitative performance assessments demonstrate significant learning gains across all components of scientific problem-solving.

Conclusion

The analysis showed that students improved notably in their scientific problem-solving competencies as a result of the instructional intervention. Specifically: **Problem Identification:** Students successfully identified the problems embedded in the teacher-created scenarios in 90% of cases. This high performance indicates that young learners can recognize scientifically framed problems when they are presented in relatable, real-world contexts. **Problem Analysis:** Initially, only a few student groups could analyze the root causes of the problems. However, through repeated engagement across four structured activities, performance in this area improved significantly rising to 75% by the final activity. This progressive improvement illustrates the value of scaffolding and

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

iteration in developing analytical skills. **Solution Proposal and Evaluation:** All student groups (100%) were able to propose suitable problem-solving methods and evaluate their results by the final activity. This reflects mastery in the latter stages of the problem-solving cycle and demonstrates that primary students, when supported through structured inquiry, can engage in high-level reasoning and reflection.

From a quantitative perspective, the comparison between pre- and post-tests showed a statistically significant improvement in scientific problem-solving scores. The mean post-test score (M = 29.79, SD = 3.02) was higher than the pre-test score (M = 24.21, SD = 2.28), with significance at the .01 level. The increase in standard deviation indicates a wider distribution of scores, suggesting that while overall achievement increased, learners responded differently to the PBL process highlighting diverse pathways of cognitive development.

Prior to instruction, 60.53% of students were at a moderate level of problem-solving proficiency. After the implementation of PBL, 74.43% of students reached a high level of proficiency. These results validate the impact of the PBL model in fostering meaningful learning gains, consistent with previous findings (e.g., Suratmi et al., 2025; Joseph, 2019), which emphasized the role of PBL in promoting energy literacy and scientific engagement.

Implications

Implications for classroom practice: This study confirms that PBL is not only feasible but highly effective for use in primary science classrooms. Teachers should be encouraged to implement real-life, scenario-based lessons that allow students to engage in identifying problems, analyzing information, designing solutions, and evaluating outcomes. The integration of tools like mind maps and collaborative discussions further supports cognitive development.

Implications for curriculum design: Curriculum developers should consider embedding structured problem-solving frameworks into science units at the elementary level. The use of sequential, real-world problem scenarios supports inquiry-based learning and aligns with competency-based educational reforms.

Implications for assessment: The four-domain rubric developed in this study (identification, analysis, solution, evaluation) offers a reliable framework for assessing scientific problem-solving in young learners. This approach allows for both formative and summative assessments that go beyond traditional multiple-choice formats.

Implications for policy and reform: The results provide empirical evidence supporting the inclusion of PBL within national education policies aimed at promoting 21st-century skills, such as critical thinking, creativity, and collaboration. This model also supports equity by enabling all learners to engage in high-level cognitive tasks, regardless of background.

Implications for future research: Further studies could explore the long-term impact of PBL on student achievement, as well as its effectiveness in other scientific topics and among different age groups. Additionally, researchers should examine how PBL interacts with digital tools and local contexts to enhance personalized learning pathways.

ACKNOWLEDGEMENTS

We would like to thank the School of Elementary Teacher Training and Education, Phuket Rajabhat University, for supporting this research. We would also like to express our gratitude to the Grade-3 elementary school students who participated as the research group.

REFERENCES

Biggs, J., & Tang, C. (2011). *Teaching for quality learning at university* (4th ed.). McGraw-Hill Education.

Brookhart, S. M. (2013). *How to create and use rubrics for formative assessment and grading*. ASCD.

Bybee, R. W. (2002). *Learning science and the science of learning*. NSTA Press.

Dwyer, C. P., Hogan, M. J., & Stewart, I. (2017). An Integrated Critical Thinking Framework for the 21st Century. Thinking Skills and Creativity, 12, 43–52.

Hosnan, M. (2014). Pendekatan Saintifik dan Kontekstual dalam Pembelajaran Abad. *Jurnal Pendidikan Pascasarjana Universitas Qomaruddin,* 1(2), 118-128.

Huitt, W. (1992). *Problem solving and decision making: Consideration of individual differences using the Myers-Briggs type indicator*. Journal of Psychological Type, 24(1), 33–44.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

Joseph, E., Melfei, E. (2019).Problem-Based Learning Approach Enhancing The Problem Solving Skills In Chemistry of Hight School Students. *Journal of Technology and Science Education*, 9(3): 3484-3498.

Joseph, E., & Melfei, E. (2019). Problem-based learning approach enhancing the problem solving skills in chemistry of high school students. *Journal of Technology and Science Education, 9*(3), 348–359.

Jonassen, D. H. (2000). *Toward a design theory of problem solving*. Educational Technology Research and Development, 48(4), 63–85.

Kemmis, S., & McTaggart, R. (2008). The action research planner (3rd ed.). Victoria, Australia: Deakin University Press.

Lye, S. Y., Wee, L. K., Kwek, Y. C., Abas, S., & Tay, L. Y. (2014). *Design, customization and implementation of energy simulation with 5E model in elementary classroom* [Conference paper]. International Conference on Teaching and Learning with Technology (iCTLT), Singapore.

Mayer, R. E., & Wittrock, M. C. (2006). Problem solving. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology* (2nd ed., pp. 287–303). Routledge.

Ministry of Education. (2008). Basic Education Curriculum 2008. Bangkok: Kurusapa Ladprao Publishing.

Moskal, B. M. (2000). Scoring rubrics: What, when and how? *Practical Assessment, Research, and Evaluation*, *7*(3).

Nitko, A. J., & Brookhart, S. M. (2014). *Educational assessment of students* (7th ed.). Pearson.

Office of the Educational Council. (2010). The 2007 Report of the Follow-Ups on Local Administrative Organization Education Management. Bangkok: Office of Educational Management Evaluation.

OECD. (2019). *PISA 2018 Assessment and Analytical Framework*. OECD Publishing. https://doi.org

Phumeechanya, N., & Wannapiroon, P. (2014). *Ubiquitous scaffold learning environment using problem-based learning to enhance problem-solving skills and context awareness*.

Suratmi, C., Riswan, J., Muhamad, Y., & Sardianto, M. (2025). Improving Energy Literacy Using the Problem Based Learning (PBL) Model for Elementary School Students in Grade VI. *Jurnal Elementaria Edukasia*, 8(1), 3484-3498.

Sukrisnawan, I. K. (2023). Appsmart learning application based on PBL model assisted by Articulate Storyline 3 on electrical energy material. *Jurnal Edutech Undiksha*, 11(2), 277–287.

Yuliati, L., Riantoni, C., & Mufti, N. (2018). Problem solving skills on direct current electricity through inquiry-based learning with PhET simulations. *International Journal of Instruction*, *11*(4), 123–138.

©2025 Copyright by the Science Education Association (Thailand). This article is licensed under CC BY-NC-ND 4.0.

SEAT

IJSET

Published August 30, 2025 by
Science Education Association (Thailand)
Sukhumvit 23, Bangkok, 10110, THAILAND
Tel: 66-2204-2528 Fax 66-2204-2528