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Deep Learning in Classroom Action Research to Improve Fourth-Grade Students' Learning Outcomes on Plants and Plant Types at Anuban Tapraya

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Abstract: This study aims to analyze the application of the deep learning approach in improving the learning outcomes of fourth-grade students at Anuban Tapraya School, Songkhla Province, Thailand, regarding plant-related topics and plant types. The research method used was Classroom Action Research (CAR) based on the Kemmis and McTaggart model, conducted in two cycles, each consisting of the planning, action, observation, and reflection stages. The research subjects were all 12 fourth-grade students. Data collection instruments included a learning outcome test that had been validated for validity and reliability, observation sheets, and documentation. Success was defined as individual achievement of a score of ≥75 and a class achievement rate of ≥75%. The research results show that the application of the deep learning approach can improve student learning outcomes, with the class average score increasing from 70.33 in Cycle I to 76.25 in Cycle II, and the classical mastery rate rising from 41.67% to 75%. In addition, students' learning activities improved in terms of mindful learning, joyful learning, and meaningful learning. Thus, the deep learning approach can serve as an alternative instructional strategy to improve learning outcomes and active student engagement in science education in elementary school, although these findings are still limited to the context of a single classroom and require further, broader research.
Keywords: Deep learning; learning outcomes; science; classroom action research; plants

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INTRODUCTION

Science education at the elementary-school level provides an essential foundation for developing students' critical-thinking and problem-solving skills, as well as their conceptual understanding of the surrounding environment (Asfiana et al., 2025). Rather than focusing solely on the acquisition of scientific facts and concepts, science education should also develop students' abilities to observe, interpret, and establish connections among phenomena encountered in everyday life. Therefore, science instruction should be designed to be active, contextual, and meaningful, enabling students to construct knowledge independently and apply it in authentic situations. Plants and plant classification constitute important topics in elementary science because they are directly related to the natural environment with which students interact in their daily lives.

Despite its importance, elementary science education continues to face several instructional challenges. Teaching remains largely dominated by lectures and memorization activities, positioning students as passive recipients of information and limiting their opportunities to engage in meaningful and in-depth learning. Bombjaková and Rusňáková (2025) reported that elementary-school students' understanding of plants often remains at a basic level because instruction has not sufficiently incorporated contextual and exploratory learning activities. Consequently, students may memorize plant-related concepts without being able to connect them to situations and phenomena in their immediate environment.

Anuban Tapraya is a private elementary school located in Saba Yoi District, Songkhla Province, Thailand. Although Thai is the school's official language of instruction, most teachers and students are of Malay ethnic background. This condition creates a distinctive sociolinguistic learning environment in which students are required to understand curricular content in a language that is not their first language. Such circumstances may increase the complexity of science learning, particularly for topics involving plant structures, functions, and classification. Accordingly, active, contextual, and meaningful instructional approaches are highly relevant to the learning needs of students at this school.

Preliminary observations conducted in the fourth-grade classroom at Anuban Tapraya indicated that students' science learning outcomes, particularly on the topics of plants and plant types, remained relatively low. The distribution of students' daily assessment scores is presented in Table 1.

Table 1. Preliminary observation findings

Value interval	Number of students	Percentage
90-100	0	0%
80-89	4	33,3%
70-79	1	8,3%
60-99	2	16,7%
50-59	5	41,7%

Based on the learning-outcome data from 12 students, the class achieved an average score of 67.8 and a classical mastery rate of 33.3%, with only 4 students meeting or exceeding the minimum mastery criterion of 75. These results indicate that the class had not yet achieved the expected mastery standard. During the preliminary observations, students showed limited enthusiasm for participating in lessons, experienced difficulty identifying plant parts and their functions, and were unable to relate the concepts they had learned to their surrounding environment. These difficulties appeared to result from an instructional process that relied primarily on textbooks, lectures, and teacher-led question-and-answer activities. Consequently, students had limited opportunities to participate actively and develop meaningful learning experiences.

In response to the demands of 21st-century education, various learner-centered approaches have been developed to address these instructional challenges. One approach that has recently attracted considerable attention is the educational deep learning approach. This approach emphasizes in-depth learning through students' cognitive, reflective, and emotional engagement and is founded on three interrelated principles: meaningful learning, mindful learning, and joyful learning (Azzahra & Jaya, 2025; Fahri Hidayat, 2026; Feriyanto & Anjariyah, 2024). Through this approach, students are encouraged to develop a deeper understanding of concepts, reflect on their learning experiences, and participate actively in contextual and enjoyable learning activities.

Hasanah & Pujiati (2025) emphasized that implementing a deep learning approach in elementary schools requires instructional strategies that integrate exploratory and reflective activities to promote students' active participation. Rather than merely memorizing information, students are encouraged to connect new concepts with their prior knowledge and lived experiences, thereby creating deeper and more meaningful understanding (Akbar et al., 2026; Fatimah et al., 2026; Maulidiya Nabila et al., 2025; Nurhakim et al., 2025). However, successful implementation is strongly influenced by teachers' readiness to manage the classroom and create meaningful and enjoyable learning experiences. Teacher preparedness is therefore an important factor in ensuring the effective implementation of deep learning-based instruction (Isnayanti et al., 2025; Permatasari & Hidayah, 2025).

In the present study, the deep learning approach was implemented through direct plant-observation activities, group discussions, exploration of the school environment, reflective activities, and the use of contextual learning media. These activities were designed to promote the active engagement of fourth-grade students at Anuban Tapraya and to make science learning more meaningful, enjoyable, and accessible.

Previous studies have demonstrated the potential of the deep learning approach to improve the quality of instruction. Puspita et al. (2025) and Raup et al. (2022) found that its implementation can promote meaningful learning and contribute to improved elementary students' science learning outcomes by increasing their active engagement in the learning process. Similarly, a meta-analysis conducted by Zhang & Ma (2023) showed that exploration-, project-, and inquiry-based learning, which are consistent with the principles of deep learning, positively affects students' learning outcomes and conceptual understanding.

Mandasari et al. (2025) and Pratiwi et al. (2026) further reported that the deep learning approach positively influenced elementary-school students' learning outcomes in integrated science and social studies education (IPAS). Through meaningful, reflective, and contextual learning processes, this approach can enhance conceptual understanding, critical-thinking skills, learning motivation, and active participation. Maslakah & Rochmania (2026) also concluded that deep learning-based IPAS handouts were valid, practical, and effective in improving elementary-school students' conceptual understanding and learning outcomes.

The integration of meaningful, mindful, and joyful learning has also been reported to strengthen students' conceptual understanding and interest in learning. By encouraging students to think critically and reflectively and to construct knowledge actively, deep learning shifts the instructional process beyond factual recall toward deeper and more internalized understanding. This process may contribute to more meaningful and sustainable improvements in learning outcomes (Prayoga et al., 2025; Komara et al., 2026; Lubis et al., 2026). In classroom action research conducted over two cycles, Wujut et al. (2026) similarly found that the consistent implementation of deep learning improved student engagement and learning outcomes. Interactive and meaningful instruction can encourage students to participate actively throughout the learning process while developing critical-thinking, creativity, and problem-solving skills from the elementary-school level onward (Sudarmono et al., 2025; Wu, 2022). Collectively, these findings suggest that the deep learning approach offers a promising alternative for improving the quality of elementary science education.

Nevertheless, the implementation of deep learning in Thai elementary-school settings remains underexplored. Aritonang et al. (2026) investigated the use of a deep learning approach supported by educational games among fourth-grade students at Santiwit Elementary School, Songkhla Technological College, Thailand, using an action-research design. However, their study addressed general science learning rather than a specific scientific topic. Siregar et al. (2026) also conducted a deep learning-based study in Thailand, but their research involved eighth-grade Metthayom students at Ban Mapring School in Pattani, focused on cell biology, and employed a quasi-experimental design. Thus, their study differed from the present research in terms of educational level, subject matter, and research design. Meanwhile, Sudarmono et al. (2025) examined deep learning through a literature review rather than direct classroom implementation and acknowledged that empirical research on its application in elementary schools remains limited.

To address this research gap, the present study implemented a deep learning approach in teaching plants and plant types to fourth-grade students at Anuban Tapraya School, Thailand, through Classroom Action Research. The study generated empirical evidence regarding changes in students' learning outcomes and classroom participation across successive instructional cycles. Its contextual contribution lies in integrating botanical content closely related to students' immediate environment with continuous classroom improvement through the principles of meaningful, mindful, and joyful learning. Accordingly, this study aimed to examine the implementation of the deep learning approach in improving students' learning outcomes on plants and plant types and to describe the changes in the learning process that occurred during the intervention.

METHOD

This study employs the Classroom Action Research method. Classroom action research is understood as a form of scrutiny of learning activities in the form of actions that are intentionally initiated and occur collaboratively within the classroom to improve the quality of the learning process and student learning outcomes (Machali, 2022). This study employs the Kemmis and McTaggart model, which consists of four main stages: planning, acting, observing, and reflecting (Arif & Oktafiana, 2023) .

Table 2. Research Procedures for Classroom Action Research, Cycle I and Cycle II

Stage	Cycle I	Cycle II
Planning	Developing deep learning-based teaching modules on topic plant and plant types; preparing student worksheets, preparing contextual learning materials; developing observation sheets and Cycle I assessment questions.	Revising the teaching modules based on the reflections from Cycle I; revising the student worksheets to make them more exploratory; preparing additional teaching aids in the form of images and real plant specimens; developing assessment questions for Cycle II.
Acting	Conduct plant-observation-based learning activities on school grounds; hold group discussions on the characteristics and types of plants; have students present their observations; and have the teacher lead a final reflection session.	Implement more interactive learning based on improvements from Cycle I; expand exploration of the school environment; provide students with opportunities to construct concepts independently; have teachers provide more active feedback during discussions.
Observing	Observe students' engagement in mindful, joyful, and meaningful learning; record teacher and student activities using an observation sheet; document the learning process.	Observe the increase in student engagement compared to Cycle I; record changes in learning activities using the same observation sheet; document the learning process.
Reflecting	Analyze the results of the evaluation and observations from Cycle I; identify weaknesses and barriers to learning; formulate corrective actions to be implemented in Cycle.	Analyze the results of the evaluations and observations from Cycle II; compare students' learning outcomes and activities between Cycle I and Cycle II; determine whether the success indicators have been met.

Research Subject

The subjects of this study were all 12 fourth-grade students at Anuban Tapraya School in Songkhla Province, Thailand, during the 2025/2026 school year

Research Instrument

The research instruments used included learning outcome tests and observation sheets. The learning outcome test instrument, consisting of 10 multiple-choice items, was first pilot-tested on 12 respondents to determine the validity, reliability, difficulty level, and discriminative power of the items. Validity was tested using the product-moment correlation, reliability using Cronbach's alpha coefficient, and difficulty and discriminant power were analyzed using the difficulty index and discrimination index formulas. The observation sheets were used to observe student engagement in discussion, observation, exploration, and presentation activities during the learning process.

Data analysis

Data analysis in this study employed a descriptive quantitative approach tailored to the characteristics of Classroom Action Research (CAR). Student learning outcomes were analyzed by calculating the class average, the highest score, the lowest score, and the percentage of students meeting the learning standards in each cycle. The class average was calculated using the formula:

$$\bar{X} = \frac{\sum X}{N}$$

Note:
$\bar{X}$ = Average score
$\sum X$ = Total number of students
N = Number of students

Meanwhile, the percentage of learning achievement in traditional classes is calculated using the following formula:

$$P = \frac{n_t}{N} \times 100\%$$

Note:
P = Classical learning achievement rates
n_t = Number of students who passed
N = Total number of students

This analysis was conducted during Cycle I and Cycle II to compare students' overall learning outcomes at each stage of the intervention. The subsequent data analysis focused on learning mastery based on the established Minimum achievement Criteria. Each student was deemed to have achieved mastery if their score met or exceeded the applicable KKM threshold of ≥75.

This study was deemed successful and could be terminated once the percentage of students achieving learning mastery reached ≥75% of all students in the class, indicating that the deep learning approach implemented had successfully improved student learning outcomes significantly. This study also employed descriptive qualitative data analysis to reflect on non-test data obtained through observation sheets, field notes, and documentation throughout the learning process.

RESULTS AND DISCUSSION

Instrument Analysis Results

The item validity analysis showed that most test items had correlation coefficients exceeding the critical value of r = 0.576 at the 5% significance level. In Cycle I, 12 of the 15 items met the validity criterion, whereas three items were classified as invalid.

In Cycle II, 13 items were valid and two were invalid. From the valid-item pool, 10 items were selected for use in the learning-outcome assessment administered in each cycle.

Table 3. Item validity test results

Cycle	Number of Items	Valid Items	Invalid Items
Cycle I	15	12	3
Cycle II	15	13	2

Instrument reliability was assessed using Cronbach's alpha. The coefficients obtained for the instruments used in Cycles I and II were 0.921 and 0.943, respectively, indicating very high internal consistency within the pilot sample.

Table 4. Reliability test results

Cycle	Cronbach's Alpha	Category
Cycle I	0.921	Very high
Cycle II	0.943	Very high

Cronbach's alpha coefficients greater than 0.80 generally indicate strong internal consistency. Accordingly, the instruments were considered sufficiently reliable for collecting data in this classroom action research. Nevertheless, these coefficients should be interpreted cautiously because the instrument was tested using a relatively small number of respondents.

Item difficulty analysis was conducted to determine the relative difficulty of each test item. The results showed that all 15 items assessed in both cycles were classified as moderately difficult.

Table 5. Item difficulty levels

Cycle	Easy	Moderate	Difficult
Cycle I	0	15	0
Cycle II	0	15	0

The moderate difficulty level indicates that the items were neither excessively easy nor excessively difficult for the participating students. Consequently, the items were considered appropriate for measuring students' understanding of plants and plant types at the targeted grade level.

The discrimination index was analyzed to determine the ability of each item to distinguish between students with higher and lower levels of achievement.

Table 6. Item discrimination index

Category	Cycle I	Cycle II
Excellent	10	11
Good	2	2
Fair	2	1
Poor	1	1

Most items in both cycles were classified as having good or excellent discrimination. Specifically, 12 items in Cycle I and 13 items in Cycle II were categorized as good or excellent. These results indicate that most items adequately differentiated students with higher levels of understanding from those who required additional instructional support. Items classified as poor should not be used without further revision.

Learning Outcomes

The implementation of the deep learning approach in Cycle I had not yet produced optimal learning outcomes on the topic of plants and plant types. Of the 12 participating students, only five achieved the individual mastery criterion of ≥75, corresponding to 41.67% of the class. The mean class score was 70.33, and the class-level mastery rate remained below the predetermined success criterion of 75%.

The score distribution further showed that several students continued to experience difficulty. Four students, representing 33.3% of the class, obtained scores between 60 and 69, whereas three students, or 25%, scored between 50 and 59. No student achieved a score within the highest range of 90–100. These findings indicate that the initial implementation of the intervention had not yet enabled most students to achieve the expected level of conceptual understanding.

Observations and reflections conducted at the end of Cycle I identified several interrelated factors that may have contributed to these results. First, students' active engagement during discussions and observation activities remained limited. Second, their interest and motivation had not yet developed optimally. Third, both the teacher and students were still adapting to the learning procedures, particularly environmental exploration, group discussion, presentation, and reflection. Consequently, several students remained passive and had limited opportunities to articulate, examine, and reconstruct their understanding.

This interpretation is consistent with Padilla et al. (2024), who explained that student achievement may be influenced by internal factors, including interest, motivation, and thinking skills, as well as external factors, such as instructional methods and the availability of learning facilities. However, the findings of the present study indicate that instructional factors were not independent of student characteristics. Rather, students' motivation and participation appeared to develop as the teacher improved the organization and facilitation of learning activities.

During Cycle I, the teacher was still adapting to the implementation of exploration-based learning and active discussion. Students had also not fully understood the roles expected of them during group observation and reflection. Although the class-level mastery criterion had not been met, several positive developments were observed. Students gradually became more confident in participating in discussions, conducting direct observations, and responding to questions. Their growing interest in hands-on science activities provided an important basis for refining the intervention in Cycle II.

The reflection conducted after Cycle I therefore focused on improving instructional guidance, clarifying the objectives and procedures of each activity, strengthening teacher feedback, expanding opportunities for environmental exploration, and providing more contextual visual materials and real plant specimens. These revisions were intended to ensure that active learning did not consist merely of physical participation but also involved conceptual construction and interaction. According to the ICAP framework, constructive activities, such as explaining concepts in one's own words, and interactive activities, such as discussing and jointly developing explanations, are more likely to support deeper learning than passive reception or simple task completion (Chi & Wylie, 2014).

The Cycle II results showed a clear improvement. The mean class score increased to 76.25, while the class-level mastery rate reached 75%. Of the 12 participating students, nine achieved the individual mastery criterion of ≥75. Two students, representing 16.7% of the class, scored between 90 and 100, and seven students, or 58.3%, scored between 80 and 89. One student, representing 8.3%, scored between 60 and 69, while two students, or 16.7%, scored between 50 and 59.

These results indicate that most students met the predetermined mastery criterion after the instructional process was refined. The improvement was associated with more structured discussions, direct plant observations, contextual learning media, clearer teacher guidance, and greater opportunities for students to explore and explain concepts independently. Through these activities, students were not only asked to identify plant parts and types but also to connect the observed characteristics with the concepts discussed in class.

Direct observation may have supported conceptual understanding by making abstract or text-based information more concrete. Students could observe actual plant structures, compare specimens, discuss similarities and differences, and relate their observations to concepts presented in the learning materials. The group-discussion and presentation stages further required students to organize and communicate their understanding. This interpretation is consistent with inquiry-based science instruction, in which observation, explanation, discussion, and teacher guidance function together to support conceptual learning. A meta-analysis by Furtak et al. (2012) found an overall positive effect of inquiry-based science teaching and showed that guided inquiry activities generally produced stronger learning outcomes than minimally guided student-led activities.

The teacher's role therefore remained important throughout the intervention. The observed improvement should not be interpreted as the result of unguided discovery alone. In Cycle II, the teacher provided clearer instructions, monitored group work, asked guiding questions, corrected misunderstandings, and provided feedback during discussions. These forms of scaffolding helped students direct their observations toward the intended scientific concepts.

Hands-on plant observation also created a more meaningful connection between scientific content and students' immediate environment. Students encountered plants as observable living organisms rather than only as illustrations or definitions in textbooks. This contextual connection may have increased the relevance of the material and stimulated students' curiosity. Zhang and Ma (2023) similarly reported that learning activities organized around authentic problems, collaboration, active investigation, and the application of knowledge were positively associated with academic, cognitive, and affective learning outcomes. Nevertheless, their findings concerned project-based learning more broadly; therefore, they should be regarded as supporting evidence rather than as direct confirmation of the present classroom intervention.

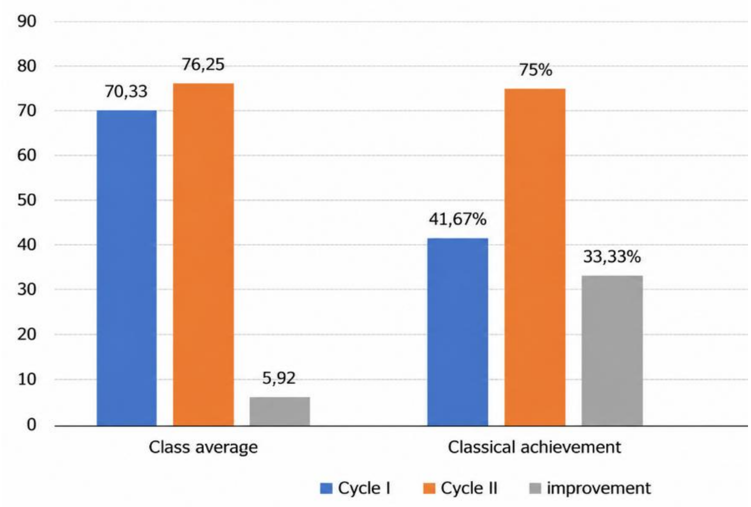

Figure 1. Learning outcomes in cycles I and II

The mean class score increased from 70.33 in Cycle I to 76.25 in Cycle II, representing an improvement of 5.92 points. The number of students who achieved the individual mastery criterion increased from five to nine. Correspondingly, the class-level mastery rate increased by 33.33 percentage points, from 41.67% to 75%. Thus, the outcome in Cycle II met the predetermined criterion for terminating the classroom action research.

Because no inferential statistical test or comparison group was used, this improvement should not be described as statistically significant or interpreted as definitive evidence of causality. Instead, the results indicate an observed improvement across the two action-research cycles following the refinement of the instructional intervention. Other factors, including repeated exposure to the material, increasing familiarity with the assessment format, and students' adaptation to the learning activities, may also have contributed to the outcomes.

Within these methodological limitations, the findings are consistent with Pratiwi et al. (2026), who reported that a deep learning approach supported elementary school students' learning outcomes in science and social studies. Meaningful, active, and reflective learning may deepen conceptual understanding by encouraging students to connect new information with previous knowledge and real-life experiences. The present study extends this argument by showing how these principles were operationalized through direct observation, group discussion, student explanation, and reflection on a specific elementary science topic.

The results are also consistent with Wu (2022), who characterized deep approaches to learning in the early grades through attention, persistence, active engagement, independent work, and an intention to understand the meaning of learning materials. In the present study, improvements in learning outcomes occurred alongside increased attention, participation, concept explanation, and cooperation. This parallel development suggests that changes in achievement and engagement may have been mutually reinforcing rather than separate outcomes.

Despite the improvement, three students did not achieve the mastery criterion in Cycle II. This finding indicates that the intervention did not benefit all students to the same extent. The available data do not permit a definitive explanation of the difficulties experienced by these students because the study did not include individual diagnostic interviews, language-proficiency measures, or detailed analyses of prior knowledge. Additional instructional cycles could therefore incorporate differentiated worksheets, smaller-group guidance, repeated concept checks, and individual remedial activities.

Overall, the comparative results suggest that the structured implementation of meaningful, mindful, and joyful learning principles was associated with improved learning outcomes in this classroom. The most plausible instructional contribution was not a single activity but the combination of direct observation, contextual materials, guided inquiry, group interaction, explanation, reflection, and teacher feedback.

Learning Process

Direct observations conducted throughout Cycles I and II showed improvements in students' cognitive, behavioral, social, and emotional engagement during the learning process.

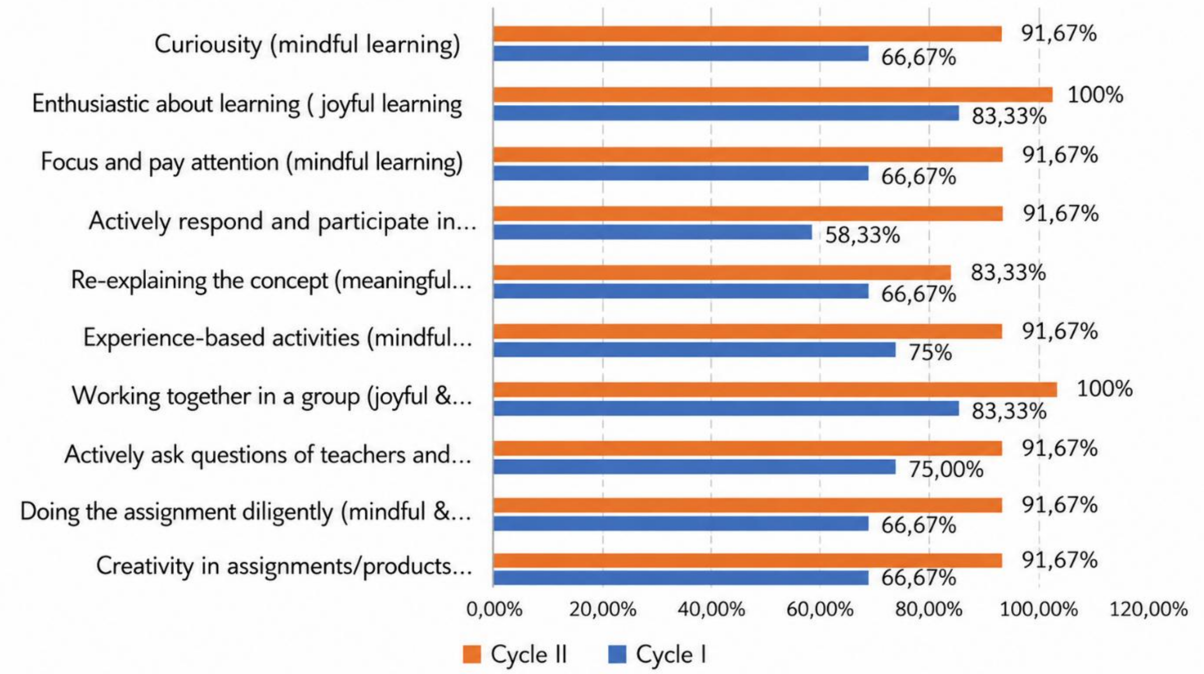

Figure 2. Learning process in cycles I and II

All observed engagement indicators increased from Cycle I to Cycle II. The most pronounced improvements occurred in students' enthusiasm for learning and cooperation during group activities, both of which increased from 83.33% to 100%. Students' active participation in answering questions and engaging in discussions increased from 58.33% to 91.67%. This change indicates that more students were willing to express ideas, respond to questions, and participate in the collective construction of knowledge.

Students' ability to restate concepts in their own words increased from 66.67% in Cycle I to 83.33% in Cycle II. This indicator is particularly important because restating a concept requires students to reorganize information rather than reproduce it verbatim. In the ICAP framework, generating explanations is classified as constructive engagement, which is expected to support deeper understanding than passive listening or the mechanical repetition of information (Chi & Wylie, 2014).

The improvements in enthusiasm and group cooperation reflected the joyful and social dimensions of the intervention. However, joyful learning should not be interpreted merely as entertainment or positive emotion. In this study, enjoyment was embedded in academically purposeful activities, including observing plants, discussing their characteristics, completing group tasks, and presenting findings. The combination of positive emotional engagement and structured cognitive activity enabled students to participate more consistently in the learning process.

The environmental observation activities supported meaningful learning by connecting scientific concepts with objects that students encountered in their immediate surroundings. Students examined real plants, identified their characteristics, compared different specimens, and linked their observations with classroom explanations. This process provided concrete referents for scientific terms and reduced dependence on memorized textbook definitions.

Mindful learning was reflected in students' increasing attention, curiosity, persistence, questioning, and ability to reflect on what they had observed. These indicators are consistent with Wu's (2022) description of deep approaches to learning, which includes attentiveness, active engagement, persistence, and an intention to understand learning materials. The results suggest that the learning environment created in Cycle II provided stronger support for these characteristics than the initial implementation in Cycle I.

The increase in group cooperation and discussion also indicates that learning became more interactive. Students had opportunities to compare observations, negotiate interpretations, and correct one another's ideas. Furtak et al. (2012) emphasized that inquiry-oriented science learning can involve cognitive, procedural, epistemic, and social dimensions. The present findings similarly suggest that direct observation was most productive when it was accompanied by discussion, explanation, and teacher-guided reflection.

These results are also supported by Maulidya et al. (2025) and Nurul Aulia et al. (2025), who reported that joyful, meaningful, and mindful learning can promote students' engagement through direct experience and reflective activities. The present findings add classroom-level evidence that these dimensions may operate simultaneously. Direct experience provided contextual meaning, group interaction created an enjoyable social environment, and reflection encouraged students to attend to and explain the scientific concepts being studied.

Moreover, Zhang and Ma (2023) found that collaborative activities centered on real-world problems can positively influence academic outcomes, thinking skills, and affective attitudes. Although the present intervention was not a full project-based learning program, it shared several relevant characteristics, including contextual tasks, small-group cooperation, active investigation, presentation, and teacher feedback. These similarities may help explain the observed development of students' participation and conceptual understanding.

Taken together, the learning-process data indicate that the intervention affected more than test performance. It was associated with changes in how students participated, cooperated, attended to scientific phenomena, communicated their understanding, and related classroom concepts to direct experience. Nevertheless, these findings were based on classroom observations and should be interpreted as descriptive evidence rather than as an independently validated measurement of psychological constructs.

Research Limitations

This study has several limitations. First, the participants consisted of only 12 fourth-grade students from a single class at Anuban Tapraya School. The findings therefore represent a specific classroom context and cannot be generalized directly to other schools, grade levels, or student populations.

Second, the study employed a classroom action research design without a comparison group. Consequently, the observed improvements cannot be attributed exclusively to the deep learning approach. Repeated exposure to the topic, familiarity with classroom procedures, teacher adaptation, and repeated assessment may also have influenced the outcomes.

Third, the intervention was implemented over only two cycles. A longer intervention would be necessary to determine whether the improvements in learning outcomes and engagement can be maintained over time and transferred to other scientific topics.

Fourth, the observation data involved a degree of subjectivity because students' engagement was assessed through researcher observations. The study did not report inter-rater agreement or independent verification by multiple observers. This limitation may have introduced observer bias, particularly because the researcher was directly involved in the instructional process.

Fifth, the validity and reliability analyses were based on a relatively small pilot sample. Although the reported coefficients indicated acceptable item validity and high internal consistency, these estimates may be unstable and should be interpreted cautiously. Future studies should pilot the instruments with a larger group that has characteristics similar to those of the research participants.

Sixth, the study was conducted in a sociolinguistic context in which Thai was the official language of instruction, while many teachers and students had a Malay linguistic background. However, students' language proficiency and the use of language-support strategies were not measured systematically. The study therefore cannot determine whether language-related factors influenced students' initial difficulties or their responses to the intervention.

Finally, the study did not collect individual diagnostic data from the three students who remained below the mastery criterion in Cycle II. Future research should incorporate interviews, analyses of prior knowledge, language-proficiency information, and differentiated assessment to identify the specific support required by students who do not respond sufficiently to whole-class interventions.

Future studies should involve larger and more diverse samples, longer intervention periods, independent observers, validated engagement measures, and comparison groups or stronger quasi-experimental designs. Such studies would provide more robust evidence regarding the effectiveness, sustainability, and generalizability of deep learning-oriented science instruction.

CONCLUSION

Based on the findings of the classroom action research conducted among fourth-grade students at Anuban Tapraya School in Songkhla Province, Thailand, the implementation of a deep learning approach was associated with improvements in students' learning outcomes and the quality of the science learning process on the topic of plants and plant types. These improvements were reflected in the increase in the class mean score and the proportion of students who met the mastery criterion from Cycle I to Cycle II, indicating that the predetermined success criteria were achieved.

In addition to improved learning outcomes, positive changes were observed across the three dimensions of the learning process: mindful learning, joyful learning, and meaningful learning. Direct plant observation and exploration of the school environment provided students with contextual and meaningful learning experiences that enhanced their curiosity, participation in classroom discussions, ability to explain scientific concepts, creativity, and collaboration within groups.

Overall, a deep learning approach that integrates meaningful, mindful, and joyful learning may serve as an alternative instructional strategy for improving learning outcomes and promoting active student engagement in elementary science education. However, the findings should be interpreted within the context of a single classroom at Anuban Tapraya School. Further research involving larger samples, multiple schools, and more rigorous research designs is therefore needed to examine the applicability and generalizability of these findings across broader educational contexts.

RECOMMENDATION

Based on the findings, teachers are encouraged to implement the deep learning approach consistently by incorporating contextual, reflective, exploratory, and collaborative learning activities into science instruction. Schools should support its implementation by providing adequate learning resources, facilitating access to appropriate instructional media, and strengthening teachers' professional competencies through relevant training and professional development programs.

Future studies may use the present research as a reference for examining the application of deep learning approaches across different subjects, grade levels, and educational settings. Further research should also investigate the integration of digital technology and instructional media, involve larger and more diverse participant groups, and employ longer intervention periods or comparative research designs to produce more comprehensive and robust findings.

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