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**Research Article**

# Development and evaluation of a game-based learning model integrated with jigsaw activity kits for food nutrition education


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**Abstract**

This study investigated students' perceptions of a learning management plan on food nutrition using Game-Based Learning integrated with jigsaw activity kits. The results indicated that students rated the learning management plan at a very high level of agreement ($\bar{X}$=4.44, SD=0.03). The highest-rated item was the clarity and appropriateness of the lesson title, followed by students' opportunities to actively engage with learning media and resources ($\bar{X}$=4.53), and the alignment of learning content with instructional time and learning indicators ($\bar{X}$=4.30). Regarding the puzzle-based learning media featuring local food images from Surin Province, students' overall perceptions were also at a very high level ($\bar{X}$=4.37, SD=0.81). The most highly rated aspects were the clarity of font size, the effectiveness of audio elements in enhancing learners' attention ($\bar{X}$=4.36), and the visual attractiveness of colorful images ($\bar{X}$=4.15). Students' perceptions of the jigsaw activity kits were rated at a very high level ($\bar{X}$=4.45, SD=0.71). The highest-rated item was the tactile quality of the materials, which facilitated ease of manipulation and play, followed by the sharpness and attractiveness of colors ($\bar{X}$=4.41) and the aesthetic appeal of the jigsaw box ($\bar{X}$=3.34). In addition, students expressed very high agreement with the quality of the instructional content on food nutrition ($\bar{X}$=4.38, SD=0.91), particularly its novelty, its ability to stimulate learning interest ($\bar{X}$=4.36), and the attractiveness of visual materials ($\bar{X}$=4.21). Overall, the integration of Game-Based Learning with jigsaw activity kits received very positive evaluations, suggesting that this instructional approach effectively enhances learner engagement, active participation, and positive learning experiences.



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## Introduction

The development of educational quality in the 21st century emphasizes the enhancement of learners' competencies in higher-order thinking, problem solving, communication, and creative use of technology in order to respond effectively to rapid social, economic, and technological changes. In Thailand, this direction is aligned with the National Education Act B.E. 1999 and the Basic Education Core Curriculum B.E. 2008, which advocate learner-centered instruction, knowledge construction through authentic experiences, and the development of key competencies, including communication, thinking, problem solving, life skills, and digital literacy (Office of the National Education Commission, 1999; Ministry of Education, 2008). At the international level, frameworks for 21st-century learning similarly highlight critical thinking, creativity, collaboration, and lifelong learning as essential capacities for sustainable human development (Partnership for 21st Century Skills [P21], 2019; OECD, 2021).


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Game-Based Learning (GBL) has emerged as a promising instructional approach that leverages the motivational and experiential qualities of games to enhance learner engagement and meaningful learning. Well-designed games provide challenge, immediate feedback, and interactive environments that promote active participation and deep cognitive processing. Empirical studies have demonstrated that GBL can significantly improve academic achievement, higher-order thinking skills, problem-solving ability, and social interaction across diverse learning contexts (Deterding et al., 2011; Hamari et al., 2016; Tokac et al., 2019). In the Thai educational context, GBL has also been increasingly adopted to support active learning and competency-based education (Hongkhuntod, 2022). In parallel, hands-on learning materials such as jigsaw activities facilitate spatial reasoning, systematic observation, persistence, and collaborative problem solving. Learners must analyze patterns, colors, and structural relationships in order to assemble fragmented pieces into a coherent whole, thereby strengthening analytical thinking and cognitive integration. Research on manipulative learning materials and interactive visual environments suggests that such activities enhance attention, conceptual understanding, and long-term retention (Fisher et al., 2014; Hattie, 2020).

Despite growing evidence supporting the effectiveness of GBL and hands-on learning tools, limited empirical research has examined the integrated use of game-based instruction combined with jigsaw activity kits in nutrition education, particularly within local and culturally contextualized learning environments. Therefore, this study aims to investigate students' perceptions of a learning management plan that integrates Game-Based Learning with jigsaw activity kits in the topic of food nutrition. The findings are expected to provide empirical evidence and pedagogical insights for designing innovative learning environments that promote active engagement, positive learning experiences, and sustainable competency development.

**Conceptual Framework of the study**

Based on a review of relevant literature and related research, this study developed a conceptual framework to examine the effects of a Game-Based Learning (GBL) instructional approach integrated with jigsaw activity kits on students' perceptions of learning in food nutrition. The framework is grounded in constructivist learning theory, which emphasizes that learners actively construct knowledge through meaningful interaction and hands-on experiences (Vygotsky, 1978; Kolb, 1984). In addition, the motivational mechanisms of game-based learning are supported by Self-Determination Theory, which highlights the roles of autonomy, competence, and relatedness in enhancing intrinsic motivation and learner engagement (Deci & Ryan, 2000), as well as Flow Theory, which explains how optimal challenge and immersion promote sustained engagement (Csikszentmihalyi, 1990). The independent variable in this study is the instructional intervention, consisting of Game-Based Learning integrated with jigsaw activity kits designed to promote active engagement, collaborative problem solving, and experiential learning. The learning activities incorporate interactive gameplay, visual puzzle-based materials, and structured tasks aligned with instructional objectives, consistent with principles of multimedia learning that support cognitive processing and meaningful learning (Mayer, 2020).

The dependent variable is students' perceptions of the learning experience, including their perceptions of the learning management plan, instructional media, jigsaw activity kits, and learning content. These perceptions serve as indicators of students' engagement, satisfaction, and perceived learning quality. The conceptual framework assumes that the integration of GBL and jigsaw activity kits positively influences students' perceptions by enhancing motivation, participation, and meaningful learning experiences, ultimately supporting learner-centered and active learning environments.

**Objectives**

- To develop and implement a Game-Based Learning lesson plan integrated with jigsaw activity kits.
- To investigate students' perceptions of the learning activities delivered through the integrated Game-Based Learning and jigsaw activity kits.

## Method

### Scope of the Study

This study defined its population as 90 undergraduate students enrolled in the Home Economics program at Surindra Rajabhat University, Thailand, across first to fourth academic years, including 25 first-year students, 20 second-year students, 27 third-year students, and 18 fourth-year students. The sample consisted of 73 students selected through purposive sampling from those who participated in the learning activities and voluntarily agreed to take part in the study.

The independent variable was the instructional approach integrating Game-Based Learning with jigsaw activity kits in the course on food nutrition within the occupational education curriculum. The dependent variable was students' perceptions of the learning management approach. The scope of the content focused on students' perceptions of the lesson plan and instructional materials designed through the integration of Game-Based Learning and jigsaw activity kits on the topic of food nutrition. The study was conducted at Surindra Rajabhat University, Mueang Surin District, Surin Province, Thailand, during the second semester of the 2023 academic year.

### Research Design

This study employed a classroom-based research design with developmental and descriptive characteristics. The purpose of the study was to develop an instructional model based on Game-Based Learning integrated with jigsaw activity kits on the topic of food nutrition and to examine students' perceptions after participating in the learning activities. The research procedures included the development of instructional materials, implementation of the instructional intervention, data collection, and data analysis using descriptive statistics.

### Participants and Sampling

The population of this study consisted of 90 undergraduate students enrolled in the Home Economics program at Surindra Rajabhat University, Thailand, during the second semester of the 2023 academic year. The population included 25 first-year students, 20 second-year students, 27 third-year students, and 18 fourth-year students.

The sample was selected using purposive sampling from students who participated in the learning activities and voluntarily agreed to complete the perception questionnaire.

### Procedure

### Game-Based Learning Lesson Plan

One lesson plan was developed for a two-hour instructional session covering the topic of food nutrition, specifically the five food groups. The lesson plan consisted of essential instructional components, including learning standards, learning objectives, key concepts, learning content, instructional procedures, learning materials and resources, assessment methods, worksheets, and appendices. The instructional process followed the principles of Game-Based Learning and was structured into three phases: introduction, learning activities, and conclusion.

The development process of the lesson plan involved reviewing the Basic Education Core Curriculum B.E. 2008 and instructional guidelines for the occupational education subject area, examining relevant theories, principles, and research related to Game-Based Learning, analyzing the alignment and coherence of instructional components, designing and developing a two-hour lesson plan, and constructing post-learning activities or assessments aligned with the learning objectives and content. The lesson plan was revised based on expert feedback prior to implementation.

### Development of Jigsaw Activity Kits

The jigsaw activity kits were developed to support the lesson plan by transforming food nutrition content into visual puzzle-based learning materials. The visual designs were created using Canva software to ensure clarity, attractiveness, and suitability for learners' cognitive levels.

The development process involved reviewing relevant principles and design concepts related to educational jigsaw materials, analyzing curriculum content aligned with the Basic Education Core Curriculum B.E. 2008, designing jigsaw components appropriate for students' learning characteristics, and submitting prototypes to the research advisor for validation and revision. The final versions of the jigsaw activity kits were refined based on expert feedback prior to classroom implementation.

**Development of the Students' Perception Questionnaire**

A students' perception questionnaire was developed to measure learners' perceptions toward the instructional approach integrating Game-Based Learning with jigsaw activity kits. The instrument consisted of 26 items measured on a five-point Likert scale. The development process included reviewing relevant literature and previous studies on perception and satisfaction measurement, defining measurement indicators and drafting questionnaire items, validating content relevance and clarity through expert review, and revising and finalizing the questionnaire prior to data collection.

Mean scores were interpreted using an interval classification method based on the class width, calculated by dividing the score range by the number of scale levels. Using class intervals for Likert scale interpretation is a common descriptive analysis practice in educational research (Alkharusi, 2022). In this study, the interval width was calculated as 0.80, and mean scores were classified from very low to very high levels of perception and satisfaction, similar to existing research that applies equal-width intervals for composite Likert scores. The classification criteria for mean score interpretation are presented as follows:

| Score | Scale Limits | Descriptive Equivalents |
|---|---|---|
| 5 | 4.21 – 5.00 | Very High Perception / Satisfaction |
| 4 | 3.41 – 4.20 | High Perception / Satisfaction |
| 3 | 2.61 – 3.40 | Moderate Perception / Satisfaction |
| 2 | 1.81 – 2.60 | Low Perception / Satisfaction |
| 1 | 1.00 – 1.80 | Very Low Perception / Satisfaction |

**Data Collection and Data Analysis**

The instructional activities were implemented according to the developed lesson plan during the second semester of the 2023 academic year. Upon completion of the learning activities, students completed the perception questionnaire. Data were collected anonymously to ensure confidentiality and protect participants' privacy. The collected data were analyzed using descriptive statistics, including mean ($\bar{x}$) and standard deviation (SD), to summarize students' overall perceptions toward the learning activities and instructional materials.

## Results

This section presents the research findings in accordance with the study objectives, which focused on the development of a learning management model based on Game-Based Learning integrated with jigsaw activity kits and the examination of students' perceptions after participating in the learning activities. The results are reported using descriptive statistics to reflect students' levels of perception toward the lesson plan, instructional materials, and learning content. These findings aim to demonstrate the appropriateness and potential effectiveness of the developed instructional approach in enhancing learner engagement and learning experiences. The results as follows:

**Development outcomes of an innovative game-based learning instructional model integrated with jigsaw activity kits**

**Results of the development of the game-based learning instructional package**

The development of a Game-Based Learning lesson plan integrated with jigsaw activity kits on the topic of food nutrition resulted in one complete lesson plan with a two-hour instructional duration, covering the content of the five food groups. The lesson plan was implemented during the second semester of the 2023 academic year. The developed lesson plan contained all essential instructional components, including learning standards, key concepts, learning objectives, learning content, instructional procedures, learning materials and resources, assessment methods, worksheets, reflective notes, and appendices.

In terms of instructional structure, the lesson was designed in accordance with Game-Based Learning principles and organized into three phases: introduction, game-based learning activities using jigsaw materials, and conclusion with reflection. This structure was intended to promote learner engagement, hands-on participation, and experiential learning. The development process was conducted systematically through curriculum analysis, review of relevant theories and research on Game-Based Learning, alignment of instructional components, and the design of learning activities appropriate for lower secondary students. Post-learning assessments consisting of 15 items were developed to align with the learning objectives.

Overall, the developed instructional package demonstrated strong alignment with curriculum standards and active learning principles. It can serve as a practical instructional model for learner-centered instruction and effective integration of game-based and interactive learning activities in food nutrition education.

**Results of the development of the jigsaw activity kits**

The development of the jigsaw activity kits for supporting instruction in food nutrition resulted in visual puzzle-based learning materials designed in accordance with the Basic Education Core Curriculum. The content focused on the five food groups and was presented through clear, colorful, and visually appealing images appropriate for students' cognitive levels. The materials were designed using Canva software to ensure systematic layout, readability, and aesthetic quality.

In terms of structural design, the jigsaw kits were developed to be durable, easy to handle, and suitable for repeated classroom use. The puzzle pieces were appropriately sized and not overly complex, facilitating group-based activities and supporting collaborative learning and process-oriented problem solving. Students were required to apply observation skills and analyze relationships among images, colors, and shapes in order to assemble the puzzles into complete representations. The development process was conducted systematically, beginning with a review of instructional media design principles and the use of jigsaw activities to promote thinking skills. Curriculum content was then analyzed to define key concepts and appropriate visual representations. Digital prototypes were developed and reviewed by experts, and revisions were made to improve content accuracy, visual clarity, and classroom usability.

Overall, the developed jigsaw activity kits demonstrated strong suitability in terms of content quality, instructional design, and usability. The materials effectively supported the Game-Based Learning approach by enhancing learner engagement, hands-on learning, and visual–cognitive processing. The jigsaw kits can be sustainably applied as instructional media in nutrition education and related subject areas.

**Results of students' perception analysis of the game-based learning lesson plan**

**Table 1.** Students' perceptions of the game-based learning lesson plan

| Evaluation Items | $\bar{x}$ (n=73) | S.D. | Description |
|---|---|---|---|
| 1. The lesson title presented in the lesson plan is clear and appropriate. | 4.55 | 0.67 | Very High |
| 2. The components of the lesson plan are complete and well-aligned. | 4.45 | 0.65 | Very High |
| 3. The key concepts are aligned with learning standards and indicators. | 4.42 | 0.71 | Very High |
| 4. The learning objectives comprehensively develop learners' knowledge, skills, and attitudes (K–P–A). | 4.40 | 0.74 | Very High |
| 5. The learning content is appropriate for instructional time and learning indicators. | 4.30 | 0.68 | Very High |
| 6. Learning activities are well-sequenced and learner-centered. | 4.32 | 0.72 | Very High |
| 7. Learning activities are diverse and practically applicable. | 4.45 | 0.71 | Very High |
| 8. Learning activities enhance students' higher-order thinking skills. | 4.44 | 0.73 | Very High |
| 9. Learning activities promote hands-on learning and knowledge construction | 4.49 | 0.69 | Very High |
| 10. Materials, instructional media, and learning resources are diverse and appropriate. | 4.51 | 0.67 | Very High |
| 11. Instructional media are aligned with learning content and learning activities. | 4.44 | 0.71 | Very High |
| 12. Students have equal opportunities to participate in using instructional media and learning resources. | 4.53 | 0.69 | Very High |
| 13. Assessment methods are aligned with learning objectives and indicators. | 4.40 | 0.70 | Very High |
| 14. The appendices contain complete assessment tools as specified in the lesson plan. | 4.47 | 0.69 | Very High |
| **Overall** | **4.44** | **0.03** | **Very High** |

As shown in Table 1, students' overall perceptions of the Game-Based Learning lesson plan were at a very high level ($\bar{x}$ = 4.44, SD = 0.03). The highest-rated item was students' opportunities to actively participate in using instructional media and learning resources ($\bar{x}$ = 4.53, SD = 0.69), followed by the clarity and appropriateness of the lesson title ($\bar{x}$ = 4.55, SD = 0.67) and the suitability of instructional materials and learning resources ($\bar{x}$ = 4.51, SD = 0.67). All evaluation items were rated at a very high level, indicating strong student agreement with the quality, alignment, and learner-centered design of the lesson plan.

**Table 2.** Students' perceptions of the local food puzzle media from Surin province

| Evaluation Items | $\bar{x}$ (n=73) | S.D. | Description |
|---|---|---|---|
| 1. The font style is attractive and visually appealing. | 4.34 | 0.73 | Very High |
| 2. The font size is clear and easy to read. | 4.37 | 0.81 | Very High |
| 3. The font color attracts learners' attention. | 4.36 | 0.73 | Very High |
| 4. The image size is well-balanced with the display. | 4.19 | 0.86 | Very High |
| 5. The images are colorful and visually attractive. | 4.15 | 0.76 | Very High |
| 6. The images are relevant and consistent with the content. | 4.32 | 0.78 | Very High |
| 7. The animated images are appropriate for learning purposes. | 4.29 | 0.77 | Very High |
| 8. The sound effects enhance learners' interest and engagement. | 4.36 | 0.79 | Very High |
| **Overall** | **4.29** | **0.77** | **Very High** |

As shown in Table 2, students' overall perceptions of the local food puzzle media were at a very high level ($\bar{x}$ = 4.29, SD = 0.77). The highest-rated item was the clarity of font size ($\bar{x}$ = 4.37, SD = 0.81), followed by the attractiveness of font color and the effectiveness of sound effects in enhancing learner engagement ($\bar{x}$ = 4.36). All items were rated at a very high level, indicating that the visual design, multimedia elements, and content relevance of the puzzle media effectively supported learners' interest and usability.

**Table 3.** Students' perceptions of the jigsaw puzzle on food nutrition

| Evaluation Items | $\bar{x}$ (n=73) | S.D. | Description |
|---|---|---|---|
| 1. The size of the jigsaw puzzle is appropriate for use. | 4.33 | 0.76 | Very High |
| 2. The shape of each puzzle piece is well-balanced. | 4.41 | 0.68 | Very High |
| 3. The colors are vivid and visually appealing. | 4.41 | 0.83 | Very High |
| 4. The surface texture provides good grip and is easy to handle during play. | 4.45 | 0.71 | Very High |
| 5. The design of the puzzle box is convenient for use. | 4.23 | 0.83 | Very High |
| 6. The puzzle box size is appropriate and easy to carry. | 4.33 | 0.73 | Very High |
| 7. The puzzle box design is colorful and visually attractive. | 3.34 | 0.28 | Moderate* |
| 8. The jigsaw activity kit is lightweight and easy to transport. | 4.32 | 0.83 | Very High |
| **Overall** | **4.35** | **0.77** | **Very High** |

As shown in Table 3, students' overall perceptions of the jigsaw activity kit were at a very high level ($\bar{x}$ = 4.35, SD = 0.77). The highest-rated item was the ease of handling due to appropriate surface texture ($\bar{x}$ = 4.45, SD = 0.71), followed by the balance of puzzle piece shapes and the vividness of colors ($\bar{x}$ = 4.41). Most items received very high ratings, indicating strong usability, visual quality, and practicality of the jigsaw kit. However, the visual attractiveness of the puzzle box received a comparatively lower rating ($\bar{x}$ = 3.34), suggesting an opportunity for further improvement in packaging design.

**Table 4.** Students' perceptions of the learning content on food nutrition

| Evaluation Items | $\bar{x}$ (n=73) | S.D. | Description |
|---|---|---|---|
| 1. The font size is well-balanced with the images. | 4.29 | 0.86 | Very High |
| 2. The font color is attractive and visually appealing. | 4.30 | 0.83 | Very High |
| 3. The images are relevant and aligned with the content. | 4.26 | 0.88 | Very High |
| 4. The images are well-balanced with the display. | 4.29 | 0.84 | Very High |
| 5. The images are colorful, attractive, and capture learners' attention. | 4.21 | 0.91 | Very High |
| 6. The level of content difficulty is appropriate for students' grade level. | 4.29 | 0.82 | Very High |

| | | | |
|---|---|---|---|
| 7. The content is accurate, complete, and consistent with the instructional topic. | 4.32 | 0.85 | Very High |
| 8. The sequencing of content presentation is logical and easy to understand. | 4.23 | 0.95 | Very High |
| 9. The content stimulates learners' interest and promotes learning engagement. | 4.36 | 0.79 | Very High |
| 10. The content is modern and innovative. | 4.38 | 0.91 | Very High |
| **Overall** | **4.31** | **0.86** | **Very High** |

As shown in Table 4, students' overall perceptions of the learning content were at a very high level ($\bar{x}$ = 4.31, SD = 0.86). The highest-rated items were the modern and innovative nature of the content ($\bar{x}$ = 4.38, SD = 0.91) and its ability to stimulate learners' interest and engagement ($\bar{x}$ = 4.36, SD = 0.79). All items received very high ratings, indicating that the content was visually well-designed, pedagogically appropriate, and aligned with learners' cognitive levels and instructional objectives.

**Table 5.** Summary of students' overall perceptions across instructional components

| Instructional Component | $\bar{x}$ (n=73) | S.D. | Description |
|---|---|---|---|
| Game-Based Learning Lesson Plan | 4.44 | 0.03 | Very High |
| Local Food Puzzle Media | 4.29 | 0.77 | Very High |
| Jigsaw Activity Kits | 4.35 | 0.77 | Very High |
| Learning Content on Food Nutrition | 4.31 | 0.86 | Very High |
| **Overall Mean** | **4.35** | — | **Very High** |

Overall, students demonstrated very high levels of perception across all instructional components (Overall Mean = 4.35). The Game-Based Learning lesson plan received the highest mean score ($\bar{x}$ = 4.44), followed by the jigsaw activity kits ($\bar{x}$ = 4.35), learning content ($\bar{x}$ = 4.31), and local food puzzle media ($\bar{x}$ = 4.29). These results indicate strong acceptance of the instructional design, learning materials, and content quality.

## Discussions

The findings of the present study provide empirical support for the development and implementation of a Game-Based Learning (GBL) instructional package integrated with jigsaw activity kits in teaching food nutrition. Consistent with the broader literature on game-based instructional design, the developed plan demonstrated comprehensive alignment with key instructional components—such as clear objectives, learner-centered sequencing, relevant content, varied learning activities, and appropriate assessment strategies—indicating its readiness for classroom implementation. These features embody best practices in GBL design that emphasize engagement through challenge, curiosity, and meaningful interaction with content (Saraiwang & Worawong, 2023; Alotaibi, 2024).

The integration of jigsaw activity kits as complementary manipulative media further supported active and collaborative learning. This aligns with research demonstrating that interactive, tangible learning tools can enhance learners' cognitive engagement by enabling them to physically manipulate elements of instructional material, thereby deepening conceptual understanding (Pan *et al*., 2025). Collaborative activities such as jigsaw tasks also resonate with findings that structured peer learning promotes social interaction, critical thinking, and shared knowledge construction (Johnson, Johnson, & Smith, 2014). Furthermore, the development process—grounded in systematic curriculum analysis and expert validation—ensured that the instructional materials reflected both pedagogical rigor and learner appropriateness, consistent with instructional design principles for multimedia learning (Mayer, 2020).

The positive student perceptions reported in this study are in line with contemporary evidence on GBL and educational games. The overall high ratings across all evaluated components suggest that learners found the lesson plan, media, and activities not only engaging but also conducive to their learning experiences. This finding mirrors broader research that GBL interventions tend to enhance student motivation, engagement, and satisfaction relative to more traditional instructional formats (Alotaibi, 2024; Adipat *et al*., 2021). Additionally, research conducted in Thai educational contexts has found that game-based and interactive learning activities can significantly improve learners' nutrition knowledge and engagement (Salaivan et al., 2020; "Nutrition-based card game," 2021), supporting the present study's results indicating positive learner perceptions toward game-oriented instructional media.

The high satisfaction with the local food puzzle media also reflects evidence that well-designed visual and interactive media can enhance user engagement and learning relevance. Educational card and puzzle games used to teach nutrition have been shown to improve conceptual understanding and promote interest in healthy eating among school-age learners (Ong, 2021). Yet, the relatively lower rating for visual attractiveness of the puzzle packaging suggests an area for improvement in future iterations of the media design, aligning with literature that aesthetic design quality can influence learners' affective engagement even when content relevance is high (Mayer, 2020).

Importantly, the strong positive perceptions across multiple dimensions—including content clarity, instructional sequencing, and media usability—echo findings from quasi-experimental studies in Thailand that game-based instruction fosters active learning and increases learners' knowledge acquisition, motivation, and engagement (Wassanasompong & Phawang, 2020; Nutrition game play research, 2020). This convergence provides evidence that GBL integrated with hands-on, interactive activities like jigsaw puzzles can be effective across age groups and subject matters, reinforcing the theoretical premise that game-aligned activities support experiential, student-centered learning.

Taken together, the current findings not only validate the effectiveness of GBL and collaborative activities in a nutrition education context but also underscore the value of well-integrated instructional design in eliciting positive learner outcomes and perceptions. As contemporary meta-analytic reviews indicate, game-based learning has moderate to large effects on learner engagement, motivation, and cognitive outcomes across educational settings (Alotaibi, 2024), the present results contribute additional support for applying GBL frameworks to health and nutrition education.

## Recommendations

- Expand the application of Game-Based Learning with interactive media across subject areas: The instructional model should be applied to other subjects requiring experiential and visual learning, such as health education, science, vocational education, and agricultural studies, to promote sustained learner engagement and active learning.
- Enhance media design quality and durability to improve learner experience: Further refinement of graphic design, packaging aesthetics, and material durability is recommended to increase usability, motivation, and long-term classroom implementation.
- Integrate reflective activities and deeper competency-based assessment: Future implementations should incorporate structured reflection and assessment of higher-order thinking, collaboration, and problem-solving skills to align with 21st-century competency frameworks.
- Strengthen teacher capacity in instructional game design: Professional development programs should emphasize instructional game design and interactive media integration to ensure sustainability and scalability of innovative learning practices.
- Extend research toward learning outcomes and comparative effectiveness: Future studies should evaluate impacts on academic achievement, cognitive skills, and behavioral outcomes, and compare this approach with alternative active learning models.

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Research Article

# A study of learning achievement using pre- and post-unit tests in an ornamental plant production course among vocational certificate students

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**Abstract**

This classroom action research aimed to examine the effects of using pre-tests and post-unit tests on students' learning achievement and practical skill development in Learning Units 4 and 5 of the Ornamental Plant Production course. The participants were 22 vocational certificate students enrolled in an agricultural program at Ratchaburi College of Agriculture and Technology during the first semester of the 2025 academic year. The research instruments consisted of achievement tests administered before instruction and at the end of each learning unit, as well as a rubric-based practical skill assessment. Content validity of the instruments was verified by three experts using the Index of Item–Objective Congruence, and reliability analysis yielded a Cronbach's alpha coefficient of .92. Quantitative data were analyzed using paired-samples t-tests to compare pre-test and post-test scores, while descriptive statistics were used to examine students' practical skill levels. The results revealed that students' post-test achievement scores in both learning units were significantly higher than their pre-test scores at the .05 level. In addition, most students demonstrated high levels of practical skills, with the majority achieving Very Good to Excellent performance levels. These findings indicate that integrating systematic pre-tests and post-unit tests can effectively enhance learning continuity, reinforce conceptual understanding, and support the development of practical competencies in vocational agricultural education. The instructional approach provides practical implications for teachers seeking to improve formative assessment practices and student-centered learning in similar vocational contexts.

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## Introduction

Ornamental plant production is a fundamental subject in agricultural education aimed at developing students' knowledge, understanding, and practical skills in plant cultivation, maintenance, and systematic crop management. The course covers essential content including the economic and social importance of ornamental plants, plant classification, factors affecting plant growth, horticultural tools and materials, basic cultivation techniques, and plant care practices. These competencies form a critical foundation for further professional development and future careers in agriculture and horticultural entrepreneurship (Office of the Vocational Education Commission [OVEC], 2023; FAO, 2022).

Contemporary educational approaches emphasize learner-centered instruction, active engagement, experiential learning, and the development of higher-order thinking and vocational competencies. Students are encouraged to actively participate in both classroom and field-based activities to construct knowledge through authentic learning

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experiences (Ministry of Education, 2022; OECD, 2021). However, in vocational agricultural classrooms, particularly in theoretical components of ornamental plant production courses, many students demonstrate limited continuity of learning due to insufficient review of previously learned content. As a result, students often struggle to connect prior knowledge with new learning tasks, leading to increased instructional time spent on repetition and reduced opportunities for hands-on practice, which is essential for skill development in vocational education.

The use of pre-tests and post-tests serves as an effective instructional and assessment strategy to promote students' preparedness, self-regulated learning, and cognitive engagement. Pre-tests help diagnose students' prior knowledge and motivate them to review relevant content before instruction, while post-tests provide evidence of learning outcomes and reinforce knowledge consolidation. Moreover, assessment data enable instructors to adjust instructional strategies and optimize learning activities based on learners' actual performance levels (Black & Wiliam, 2018; Hattie, 2020). Empirical studies consistently indicate that systematic formative assessment and the use of pre- and post-testing significantly enhance learning achievement, learning continuity, and student motivation (OECD, 2021; Panadero et al., 2019).

Within the framework of classroom action research, the systematic use of assessment tools plays a vital role in addressing real instructional problems, supporting reflective teaching practices, and promoting continuous improvement in learning quality. Action research emphasizes collaborative problem-solving between teachers and students and focuses on context-specific interventions that enhance learner development in authentic classroom environments (Kemmis et al., 2014; Wongwanich, 2021). Achievement tests are commonly used to measure students' academic knowledge, skills, and learning attainment in relation to defined instructional objectives (Rittiroung, 2002). Accordingly, this study aims to investigate the development of students' learning achievement through the use of pre-tests and post-unit tests in Learning Units 4 and 5 among second-year vocational certificate students enrolled in the Ornamental Plant Production course at Ratchaburi College of Agriculture and Technology. The study seeks to address issues related to insufficient learning continuity, enhance students' responsibility for content review, and improve the effectiveness of practice-oriented instructional activities in vocational agricultural education.

**Conceptual Framework of the Research**

Based on a review of learning theory and formative assessment principles, the use of pre-tests and post-unit tests has been widely recognized as an effective strategy for enhancing learning readiness, promoting continuity of learning, and providing concrete evidence of students' learning achievement. Therefore, this study establishes a conceptual framework focusing on the causal relationship between instruction using pre-tests and post-unit tests (independent variable) and students' learning achievement in Learning Units 4 and 5 (dependent variable). This framework serves as a guideline for research design, data collection, and systematic data analysis.

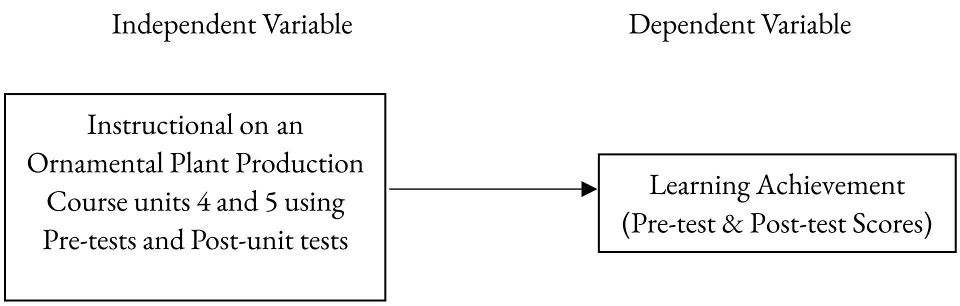


**Figure 1.** Conceptual Framework of the Research

**Research Hypotheses**

H1: Students' learning achievement in Learning Units 4 and 5 of the Ornamental Plant Production course after instruction using pre-tests and post-unit tests is significantly higher than before instruction at the .05 level.

H2: Students demonstrate high levels of practical skills after instruction using pre-tests and post-unit tests, as measured by rubric-based performance assessment.

**Objectives**

To examine the development of learning achievement of second-year vocational certificate students in the Ornamental Plant Production course using pre-tests and post-unit tests in Learning Units 4 and 5.

## Method

**Research Design**

This study employed a classroom action research approach using a one-group pretest–posttest experimental design to examine the effectiveness of pre-tests and post-unit tests on students' learning achievement. The intervention integrated systematic formative assessment at the beginning of each lesson and summative assessment at the end of each learning unit. This design is appropriate for instructional improvement in authentic classroom contexts and supports continuous reflection and pedagogical refinement (Kemmis et al., 2014; Wongwanich, 2021).

**Participants**

The participants consisted of 22 second-year vocational certificate students enrolled in the Ornamental Plant Production course at Ratchaburi College of Agriculture and Technology during the first semester of the 2025 academic year. Purposive sampling was applied because the researcher was the course instructor and aimed to directly improve instructional practice in this classroom setting. All participants completed the full sequence of learning activities and assessments.

**Research Instruments**

**Achievement Tests**

Two sets of achievement tests were developed by the researcher to assess students' knowledge in the following learning units: (1) Learning Unit 4: Factors Affecting Ornamental Plant Growth, and (2) Learning Unit 5: Horticultural Materials, Tools, and Equipment. Each unit included multiple pre-tests administered at the beginning of selected lessons (four pre-tests for Unit 4 and three pre-tests for Unit 5). Each pre-test was scored on a 40-point scale, and one post-unit test was administered at the completion of each unit using the same scoring criteria. The tests consisted primarily of open-ended questions designed to assess students' conceptual understanding, factual accuracy, and ability to apply horticultural knowledge in practical contexts. In addition, students' practical skills were evaluated using a five-level scoring rubric, with classroom teachers serving as assessors. The rubric employed five performance levels (5, 4, 3, 2, and 1) and consisted of two assessment components: (1) Process Performance, and (2) Product Quality, with each component allocated 25 points, resulting in a total score of 50 points. Performance levels were interpreted as follows:

45 – 50 points: Excellent
37 – 44 points: Very Good
29 – 36 points: Good
21 – 28 points: Fair
Below 21 points: Needs Improvement

This rubric enabled systematic and consistent evaluation of students' practical competencies during hands-on learning activities.

**Score Recording Forms**

Structured score recording forms were used to systematically collect and organize individual students' pre-test and post-test scores for subsequent statistical analysis.

**Instrument Validation and Quality Assurance**

**Content Validity**

The achievement tests were reviewed by three subject-matter experts in agricultural education and educational measurement to evaluate content relevance, clarity, and alignment with learning objectives. The Index of Item–Objective Congruence (IOC) method was applied, with each item rated on a three-point scale (-1 = incongruent, 0 = uncertain, +1 = congruent). The IOC values ranged from 0.60 to 1.00, exceeding the acceptable threshold of 0.50 and indicating satisfactory content validity for all test items (Rovinelli & Hambleton, 1977). Minor wording revisions were implemented based on expert feedback prior to classroom administration. Item discrimination indices ranged from 0.35 to 0.93, demonstrating good to excellent discriminating power. The internal consistency reliability of the achievement tests was examined using Cronbach's alpha coefficient, yielding a reliability value of α = 0.92, which indicates a high level of measurement reliability.

In addition, students' practical skills were assessed using a five-level scoring rubric. The rubric was evaluated by experts for content validity and coverage of practical skill competencies using the IOC method. The rubric was subsequently pilot-tested with a group of students who were not part of the research sample to examine clarity, feasibility, and usability. Revisions were made based on pilot feedback before final implementation in the study.

**Scoring Consistency and Reliability Control**

All tests were scored using an analytic rubric with four performance levels (0–3 points per response), emphasizing accuracy, completeness, and conceptual clarity. The researcher served as the primary scorer and conducted double-check scoring to minimize clerical and judgmental errors. Consistent scoring procedures were applied across all testing sessions. Although inter-rater reliability was not calculated due to single-rater scoring, rubric-based scoring and repeated verification were implemented to enhance scoring reliability (Brookhart, 2018).

**Data Collection Procedure**

The data collection process was conducted over an eight-week instructional period and followed these steps:

- Students were informed that pre-tests would be administered at the beginning of each lesson to encourage systematic review and preparation.
- Pre-tests for Learning Unit 4 were administered on four occasions (June 29, June 30, July 6, and July 7, 2025).
- The post-unit test for Unit 4 was administered on August 13, 2025.
- Pre-tests for Learning Unit 5 were administered on three occasions (August 14, August 17, August 20, and August 23, 2025).
- The post-unit test for Unit 5 was administered on August 27, 2025.
- All scores were recorded using standardized score recording forms and verified prior to analysis.

**Data Analysis**

Descriptive statistics (mean and standard deviation) were used to summarize students' pre-test and post-test scores. Paired-samples t-tests were conducted to examine statistically significant differences between pre-test and post-test scores for each learning unit at the .05 significance level. Statistical analyses were performed using standard statistical software.

## Results

The results of this study are presented to examine the effects of instructional intervention using pre-tests and post-unit tests on students' learning achievement and practical skill development in Learning Units 4 and 5. Quantitative analyses were conducted using paired-samples t-tests to compare students' pre-test and post-test achievement scores. In addition, descriptive statistics were used to analyze the distribution of students' practical skill levels based on rubric-based performance assessments. Tables 1 and 2 present the comparisons of learning achievement before and after instruction for Learning Units 4 and 5, respectively, while Tables 3 and 4 summarize the distribution of students' practical skill levels in both learning units.

**Table 1.** Comparison of students' learning achievement before and after instruction learning Unit 4: Factors Affecting Ornamental Plant Growth (n = 22)

| Test | N | Maximum Score | Mean | SD | df | t | P (Sig) |
|---|---|---|---|---|---|---|---|
| Pre-test | 22 | 20 | 9.95 | 2.39 | 21 | 18.64 | .001 |
| Post-test | | | 16.82 | 1.68 | | | |

As shown in Table 1, the mean pre-test score was 9.95 (SD = 2.39), while the mean post-test score increased to 16.82 (SD = 1.68) out of a maximum score of 20. A paired-samples t-test revealed that the post-test scores were significantly higher than the pre-test scores (t = 18.647, df = 21, p = .001), indicating that the instructional intervention in Learning Unit 4 effectively improved students' learning achievement.

**Table 2.** Comparison of students' learning achievement before and after instruction learning Unit 5: Horticultural Materials, Tools, and Equipment (n = 22)

| Test | N | Maximum Score | Mean | SD | df | t | P (Sig) |
|---|---|---|---|---|---|---|---|
| Pre-test | 22 | 20 | 10.64 | 3.24 | 21 | 12.36 | .001 |
| Post-test | | | 17.27 | 2.00 | | | |

Table 2, shows that the mean pre-test score was 10.64 (SD = 3.24), whereas the mean post-test score increased to 17.27 (SD = 2.00) out of 20 points. The paired-samples t-test demonstrated a statistically significant difference between pre-test and post-test scores (t = 12.36, df = 21, p = .001), suggesting that the instructional intervention in Learning Unit 5 significantly enhanced students' learning achievement.

**Table 3.** Students' practical skill levels in learning unit 4: factors affecting ornamental plant growth (n = 22)

| Performance Level | Score Range | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Excellent | 45 – 50 | 2 | 9.09 |
| Very Good | 37 – 44 | 14 | 63.64 |
| Good | 29 – 36 | 4 | 18.18 |
| Fair | 21 – 28 | 2 | 9.09 |
| Needs Improvement | Below 21 | 0 | 0.00 |
| **Total** | | **22** | **100.00** |

As shown in Table 3, the majority of students demonstrated high levels of practical skills in Learning Unit 4. Specifically, 63.64% of students were classified at the Very Good level and 9.09% achieved the Excellent level. Additionally, 18.18% of students were rated as Good, while 9.09% were at the Fair level. No students were classified as Needs Improvement. These findings indicate that most students developed strong practical competencies in applying procedures related to ornamental plant growth.

**Table 4.** Students' practical skill levels in learning unit 5: horticultural materials, tools, and equipment (n = 22)

| Performance Level | Score Range | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Excellent | 45 – 50 | 1 | 4.55 |
| Very Good | 37 – 44 | 11 | 50.00 |
| Good | 29 – 36 | 6 | 27.27 |
| Fair | 21 – 28 | 2 | 9.090 |
| Needs Improvement | Below 21 | 2 | 9.090 |
| **Total** | | **22** | **100.00** |

Table 4, presents the distribution of students' practical skill levels in Learning Unit 5. The results show that 50.00% of students achieved the Very Good level, followed by 27.27% at the Good level and 4.55% at the Excellent level. Additionally, 9.09% of students were classified as Fair, while 9.09% were identified as Needs Improvement. Although the majority of students demonstrated satisfactory to high practical skill levels, a small proportion still required further support to strengthen their practical competencies in the use of horticultural materials and equipment.

**Summary**

Based on the analyses presented in Tables 1–4, the instructional intervention using pre-tests and post-unit tests significantly enhanced both students' learning achievement and practical skill development. The post-test mean scores for Learning Units 4 and 5 were significantly higher than the pre-test mean scores (t = 18.647, p = .001; t = 12.36, p = .001, respectively), indicating the effectiveness of continuous formative assessment and structured review activities. In addition, rubric-based performance assessment revealed that the majority of students achieved Very Good to Excellent levels of practical skills. Specifically, 72.73% of students in Learning Unit 4 and 54.55% in Learning Unit 5 demonstrated high performance levels, with only a small proportion of students requiring additional support. Overall, the findings suggest that the instructional approach effectively supported both cognitive achievement and practical competency development.

Based on the paired-samples t-test results, Hypothesis 1 was supported, as students' post-test achievement scores were significantly higher than pre-test scores in both learning units. Furthermore, descriptive analysis of rubric-based performance assessment supported Hypothesis 2, indicating that most students demonstrated high levels of practical skills after instruction.

## Discussion

The findings of this study clearly demonstrate that integrating multiple pre-tests and post-unit tests significantly enhanced students' learning achievement in both Learning Unit 4 and Learning Unit 5. The paired-samples t-test results indicated statistically significant improvements in post-test scores compared with pre-test scores (Unit 4: $t = 18.64$, $p = .001$; Unit 5: $t = 12.36$, $p = .001$). These results support the principles of formative assessment and assessment for learning, which emphasize the continuous use of assessment information to guide instructional improvement and promote student learning (Black & Wiliam, 2009; Sortwell et al., 2024).

One plausible explanation for the observed learning gains is the retrieval practice effect, which posits that actively recalling information through frequent testing strengthens memory consolidation and long-term retention more effectively than passive review (Agarwal & Bain, 2019; Kobayashi, 2022). In this study, repeated pre-tests encouraged students to retrieve previously learned content at the beginning of each lesson, reinforcing conceptual understanding and promoting learning continuity. Recent empirical evidence also suggests that retrieval practice not only enhances factual recall but also supports the application of complex concepts and transfer of learning (Corral et al., 2025). This mechanism likely contributed to the substantial improvement in achievement scores observed across both learning units.

In addition, the instructional strategy aligns with the pretesting effect, which indicates that attempting to answer questions before formal instruction—even when responses are initially incorrect—can stimulate curiosity, activate prior knowledge, and increase attention to subsequent learning materials (Little & Bjork, 2016; Mera, 2025). The repeated exposure to pre-tests in this study may have promoted metacognitive awareness and self-regulated learning, enabling students to identify knowledge gaps and focus their study efforts more effectively. This interpretation is consistent with Thai educational research emphasizing the role of formative assessment in supporting learners' reflection and continuous improvement (Metinee Thanongkit, 2022).

Beyond cognitive outcomes, the rubric-based assessment of practical skills revealed that most students achieved Very Good to Excellent performance levels in both learning units, particularly in Learning Unit 4, where no students were classified as needing improvement. These findings suggest that structured formative assessment combined with hands-on learning activities can effectively support the development of procedural competence and task accuracy in vocational education contexts. Rubric-based assessment has been widely recognized as a reliable approach for evaluating performance-based skills, as it clarifies expectations, enhances scoring consistency, and provides meaningful feedback for learners (Brookhart, 2018; Yousef & Ayyoub, 2024).

However, a small proportion of students in Learning Unit 5 remained at the Needs Improvement level, indicating that practical competencies related to the use of horticultural materials and equipment may require additional instructional scaffolding. This outcome may reflect the higher complexity and safety requirements associated with equipment handling, which often demand extended practice, demonstration, and guided supervision. Previous studies in vocational and technical education have emphasized the importance of deliberate practice, step-by-step modeling, and immediate feedback to support skill mastery, particularly for learners with lower initial proficiency (Ericsson & Pool, 2016; Wu et al., 2025). Therefore, supplementary strategies such as micro-practice sessions, safety checklists, peer coaching, and reflective feedback could further enhance practical skill development in future implementations.

Overall, the findings highlight three major implications. First, systematic use of pre-tests and post-unit tests functions effectively as formative assessment and retrieval practice, leading to significant improvements in learning achievement.

Second, rubric-based performance assessment supports the development of practical competencies and provides meaningful evidence of skill progression. Third, differentiated instructional support remains necessary for learners who experience difficulty in complex practical tasks, particularly in equipment-based activities. These implications reinforce the value of integrating assessment-driven instruction within vocational agricultural education to promote both cognitive and practical learning outcomes.

## Recommendations

### Recommendations for Stakeholders

- Integrate systematic pre-testing and post-unit assessment into routine instruction. Educational institutions and instructors should embed regular pre-tests and post-unit tests as part of daily classroom practice to promote learning continuity, retrieval practice, and formative feedback. This approach can enhance students' preparedness and reinforce conceptual understanding, particularly in vocational and skills-based subjects.
- Use rubric-based performance assessment to strengthen practical skill development. Teachers should adopt well-designed scoring rubrics to evaluate students' practical competencies, as rubrics provide transparent expectations, consistent scoring, and actionable feedback. Continuous rubric-based assessment can support students' self-monitoring and improve the quality of hands-on learning outcomes.
- Provide targeted instructional support for learners with lower practical proficiency. Students who demonstrate fair or low performance levels, especially in complex equipment-based activities, should receive additional scaffolding, such as guided practice, micro-skills training, safety simulations, and individualized feedback to reduce performance gaps and promote equitable skill development.

### Recommendations for Future Research

- Examine the long-term retention and transfer effects of repeated pre-testing. Future studies should investigate whether learning gains from multiple pre-tests persist over longer periods and whether students can transfer acquired knowledge and skills to new contexts, real-world tasks, or advanced coursework.
- Explore comparative and mixed-method research designs. Further research may compare different formative assessment strategies (e.g., retrieval practice, peer assessment, digital quizzes, adaptive testing) or integrate qualitative methods such as interviews and classroom observations to better understand learners' cognitive, motivational, and behavioral responses.

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**Research Article**

# Community resilience and climate change adaptation based on soil erosion assessment: A case study at Loei

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**Abstract**

This study investigates community resilience and adaptation strategies to mitigate the impacts of climate change, with a particular focus on soil erosion in vulnerable agricultural landscapes. Employing a Participatory Action Research (PAR) approach within the Thai Prachapijai (Participatory Research and Development: PR&D) framework, the research integrates scientific analysis with community-based problem-solving processes. Twenty community participants from climate-affected areas were actively engaged in data collection, experimentation, and knowledge exchange. The study compares agricultural plots with and without soil conservation measures to evaluate the effectiveness of erosion control practices. Eight experimental plots, each measuring one cubic meter in width, length, and depth, were established to quantify annual soil loss. Four plots were located in the upstream Man River area (Ban Mak Khaeng, Kok Sathon Subdistrict), characterized by steep-slope cultivation, while the remaining four plots were situated in the Phung Phung basin, where soil conservation practices have been implemented. Over a three-year observation period, key variables—including rainfall intensity, vegetation management, soil conservation techniques, slope gradient, soil properties, and erosion risk—were systematically monitored and analyzed. Annual soil loss data were processed to estimate erosion rates and generate spatial maps illustrating erosion severity across the study areas. The results enable identification of critical factors influencing soil erosion and assessment of the effectiveness of conservation interventions. The findings are disseminated to local communities to strengthen adaptive capacity, enhance evidence-based decision-making, and promote sustainable land management practices. Ultimately, this research contributes to practical strategies for improving soil conservation, enhancing community resilience, and reducing climate change vulnerability in smallholder agricultural systems.

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## Introduction

Climate change has emerged as a critical global challenge affecting food security, ecosystem stability, and the sustainability of agricultural communities, particularly in developing countries that are highly vulnerable to increasing climate variability and extreme weather events. Intensified rainfall, shifting precipitation patterns, and land-use pressures accelerate soil degradation and soil erosion processes, thereby undermining agricultural productivity and ecosystem services (IPCC, 2022; FAO, 2023). In Thailand, a substantial proportion of agricultural land is located in

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sloping and erosion-prone areas. National soil resource assessments indicate that more than half of the country's land area exhibits physical or chemical limitations for agricultural use or lies within complex mountainous terrains requiring careful soil management (Land Development Department, 2023). Continuous reliance on chemical fertilizers in intensive farming systems further exacerbates soil quality deterioration and chemical accumulation risks (Department of Agriculture, 2022).

Long-term erosion assessments reveal that although most areas experience low average soil loss, certain lowland and upland regions exhibit moderate to severe erosion risks, closely associated with rainfall intensity, topographic characteristics, and inappropriate land-use practices. These patterns align with broader trends observed across Southeast Asia under climate change conditions (Shrestha et al., 2021; Panagos et al., 2022). At the community level, the concepts of community resilience and climate change adaptation have gained increasing recognition as essential frameworks for reducing vulnerability and enhancing adaptive capacity in agricultural systems. Participatory approaches that integrate local knowledge, experiential learning, and evidence-based decision-making are increasingly emphasized for sustainable land and water management (Folke et al., 2021; Tanner et al., 2022).

Nevertheless, many existing studies primarily focus on technical modeling or macro-scale assessments, while empirical studies that integrate field-based soil erosion measurements with participatory learning processes at the community scale remain limited, particularly in mountainous watershed contexts of Thailand. This study therefore aims to enhance community resilience and climate change adaptation through a participatory action research (PAR) approach under the Thai Prachapijai (Participatory Research and Development: PR&D) framework. The research empirically quantifies soil loss in agricultural plots with and without conservation measures in the Pung–Mun watershed, Dansai District, Loei Province, Thailand. The findings are expected to strengthen community-based decision-making, improve adaptive land management strategies, and support sustainable agricultural development under changing climatic conditions.

**Objectives**

- To collect and analyze soil loss data influenced by human activities and rainfall intensity under climate change conditions.
- To compare the magnitude and characteristics of soil erosion between agricultural plots with soil conservation measures and those without conservation practices.
- To synthesize and propose site-specific strategies for reducing soil loss and promoting sustainable soil management in agricultural areas.

**Research Problem**

This study addresses one main research question and four sub-research questions as follows: What are the key drivers of soil erosion and spatial patterns of soil loss in the Pung and Man watersheds and adjacent agro-ecological landscapes? The sub-questions investigate:

- How does land-use conversion to monoculture agriculture influence soil erosion rates?
- What is the relationship between rainfall variability and soil loss under climate change conditions?
- How do slope gradient, soil properties, and geological characteristics affect soil erosion susceptibility?
- Which soil and water conservation measures are most effective and context-appropriate for reducing soil erosion in the Pung and Man watersheds?

## Method

**Research Design**

This study employed a Participatory Research and Development (PR&D) framework integrated with Participatory Action Research (PAR). The approach emphasizes active community engagement throughout problem identification, field data collection, experimental implementation, and knowledge synthesis, aiming to strengthen local adaptive capacity to climate change while generating empirical scientific evidence.

**Study Area and Study Period**

The study was conducted in the Pung and Man watersheds, Dansai District, Loei Province, Thailand. The region is characterized by upland terrain with slope gradients ranging approximately from 25° to 50°, making it highly susceptible to soil erosion. Data collection was carried out over a three-year period from July 1, 2020, to June 30, 2023, allowing assessment of interannual variability in rainfall patterns and soil erosion dynamics.

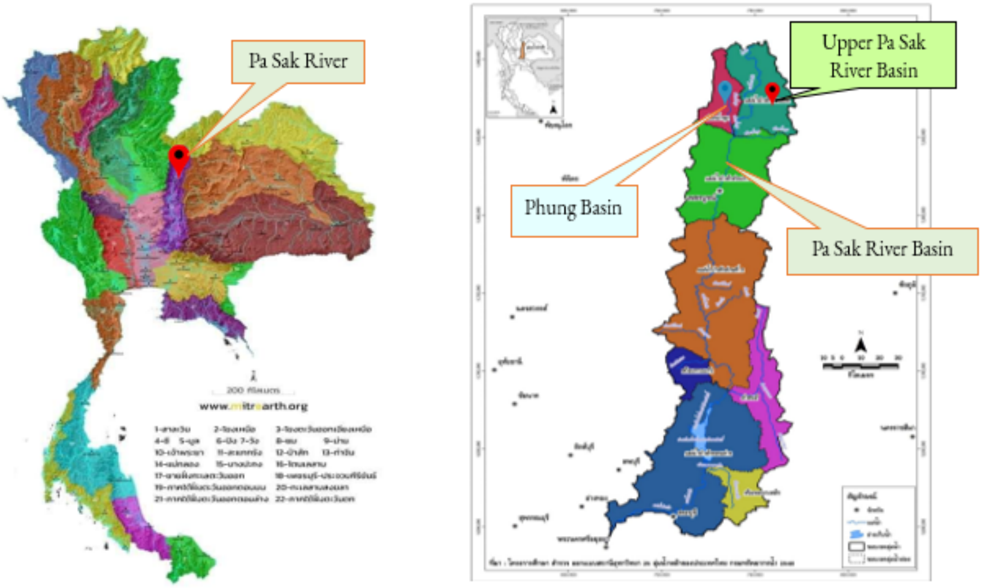


**Figure 1.** Location of the study area in Dansai district, Loei province, Thailand

**Research Instruments**

Data collection instruments included:

- rain gauges for measuring rainfall amount and intensity;
- soil sampling tools (spades, knives, measuring tapes, and sample containers);
- field tools for recording crop growth and yield;
- measuring rods for monitoring surface soil level changes; and
- leveling materials for defining plot boundaries and ensuring consistent plot conditions.

**Soil Loss Monitoring Protocol**

Soil loss from each experimental plot was monitored continuously and aggregated annually. After each significant rainfall event, eroded soil and sediment accumulated within plot boundaries and downslope collection zones were collected. Samples were air-dried and oven-dried at 105°C until constant weight was achieved. Dry mass was measured using a digital balance and recorded in kilograms.

Annual soil loss per plot was calculated by summing dry sediment mass from all rainfall events and converting values to soil loss rates (t $ha^{-1}$ $yr^{-1}$) based on plot surface area and bulk density conversion factors. Surface soil level changes were verified using fixed reference markers installed in each plot.

Quality control included duplicate weighing, routine calibration of balances and rain gauges, and cross-checking field records by both researchers and community co-researchers.

**Universal Soil Loss Equation (USLE) Factor Estimation**

Annual soil loss was estimated using the Universal Soil Loss Equation (USLE):

$$A = R \times K \times LS \times C \times P$$

where $A$ is average annual soil loss (t $ha^{-1}$ $yr^{-1}$), $R$ is rainfall erosivity, $K$ is soil erodibility, $LS$ is sloping length and steepness, $C$ is cover-management, and $P$ is supporting practice factor.

- R factor: Derived from on-site rain gauge data and nearby meteorological stations using regional erosivity equations for tropical monsoon climates.

- K factor: Determined from soil texture, organic matter, structure, and permeability using standard erodibility nomographs.
- LS factor: Calculated from field slope measurements and digital elevation models (DEM) using GIS-based analysis.
- C factor: Assigned based on crop type, vegetation cover, and seasonal management practices.
- P factor: Determined according to conservation practices such as contour farming, vegetative barriers, bamboo stabilization, mulching, and reduced tillage.

USLE estimates were compared with measured soil loss to support model validation.

**Data Analysis and Spatial Mapping**

Comparative analysis was conducted between conserved and non-conserved plots. Correlation analysis was applied to examine relationships between erosion drivers and soil loss. Spatial analysis was performed using Geographic Information Systems (GIS) to generate erosion severity maps and visualize spatial patterns.

**Data Reliability and Validation**

Data reliability was ensured through standardized protocols, periodic instrument calibration, triangulation between measured data and USLE estimates, and participatory verification with community co-researchers. Annual datasets were reviewed for anomalies and missing values prior to analysis.

**Ethical Considerations**

All participants provided informed consent prior to participation. Personal identifiers were anonymized in all datasets and publications. Participation was voluntary, and participants could withdraw at any time without consequence.

**Operational Definitions**

For clarity and consistency, key terms used in this study are defined as follows.

*Soil erosion and soil loss.* Soil erosion refers to the detachment and transport of soil particles by rainfall impact and surface runoff processes. Soil loss in this study specifically refers to the measured mass of detached surface soil collected from experimental plots and expressed as annual soil loss rates (t $ha^{-1}$ $yr^{-1}$).

*Soil and water conservation measures.* Soil and water conservation measures refer to physical and biological practices applied to reduce runoff, enhance soil stability, and minimize soil erosion, including vegetative cover, reduced tillage, bamboo stabilization, mulching, contour-based practices, and agroforestry systems implemented in the study sites.

*Climate change.* Climate change refers to long-term alterations in average weather patterns, including temperature, precipitation, and the frequency and intensity of extreme events, driven by both natural variability and anthropogenic influences.

*Climate change adaptation and community resilience.* Climate change adaptation refers to adjustments in agricultural practices, land management, and community systems to reduce vulnerability and enhance adaptive capacity to climate-related risks. Community resilience refers to the ability of local communities to anticipate, absorb, adapt to, and recover from climate-related disturbances through participatory learning and adaptive management practices.

*Green infrastructure (optional).* Green infrastructure refers to strategically managed natural and semi-natural ecosystems that provide ecosystem services such as erosion control, carbon sequestration, biodiversity conservation, and disaster risk reduction.

## Results

**General Characteristics of the Study Area**

The study area is located in Dansai District, Loei Province, northeastern Thailand, covering Pong and Kok Sathon subdistricts. The total study area is approximately 450 $km^2$, comprising 12 target villages. The landscape is predominantly mountainous with elevations ranging from 700–800 m above sea level and reaching over 1,700 m in parts of Kok Sathon.

Geologically, the area is dominated by the Sao Khua Formation (Jsk), consisting mainly of siltstone, mudstone, and sandstone, covering approximately 374.81 $km^2$. Secondary formations include the Phu Phan Formation (Kpp) and Phu

Kradung Formation (Jpk), which exhibit different weathering and erosion susceptibilities, influencing slope stability and landslide occurrence.

The regional climate is controlled by tropical monsoon systems with three distinct seasons: rainy (June–October), cool (November–February), and hot (March–May). Average annual rainfall ranges from approximately 1,100–1,200 mm, with peak rainfall occurring in September. Plot-level observations (2019–2021) indicate an average annual cumulative rainfall of approximately 1,540 mm and a mean annual temperature of 24.6°C, reflecting high moisture availability and rainfall variability conducive to soil erosion processes.

Soil resources are dominated by Soil Group 62, accounting for approximately 58.93% of the district area. These soils occur on steep mountainous terrain (>35% slope), are generally shallow with exposed rock fragments, and exhibit limited suitability for monoculture cropping, resulting in high erosion susceptibility. Soil Group 29 is the secondary dominant soil type, occurring on gently to moderately sloping terrain (3–25%) with greater agricultural potential.

Groundwater potential in both sub-districts ranges from moderate to high, with many areas capable of yielding 2–10 $m^3 h^{-1}$, supporting agricultural water supply during dry periods.

The study area is highly exposed to multiple natural hazards, particularly landslides and soil erosion. Approximately 67.64% of Dansai District is classified as landslide-prone. Both Pong and Kok Sathon subdistricts exhibit moderate to high landslide and erosion susceptibility. In addition, drought risk ranges from low to moderate due to seasonal rainfall variability and limited water storage infrastructure.

Overall, the combined effects of steep topography, erodible geological formations, monsoon-driven rainfall variability, and vulnerable soil conditions highlight the high sensitivity of the Pung and Man watersheds to soil erosion and climate-related risks, providing a suitable setting for evaluating conservation effectiveness and community-based adaptation strategies.

**Geo-social Mapping and Participatory Water Management**

Findings indicate that the Geo-social Map for integrated community-based water management serves as a practical participatory planning tool. The mapping process enhances community understanding of local environmental settings, water resources, and flood–drought problems, while systematically capturing community needs and recommendations. The resulting datasets support the development of an actionable, multi-agency action plan at village and subdistrict levels. Importantly, soil erosion risk information can be integrated as a core thematic layer within geo-social mapping to strengthen risk communication and guide context-appropriate soil and water conservation planning.

**Spatial and Temporal Patterns of Soil Erosion Severity in the Man and Phung Watersheds**

This section presents the spatial distribution and temporal dynamics of soil erosion severity in the Man and Phung watersheds based on multi-year erosion assessments and comparative analysis. The results summarize changes in erosion intensity across different severity classes, highlighting patterns of low-, moderate-, and high-risk areas over time. Comparative analysis between watersheds further illustrates how geomorphological conditions, land-use practices, and conservation interventions influence erosion trajectories. The findings provide an empirical basis for identifying erosion hotspots, evaluating long-term trends, and supporting evidence-based soil and water conservation planning at the watershed scale.

**Table 1.** Soil erosion severity in the man sub-watershed (2002 vs. 2020)

| Class | Severity Level | Soil Loss ($t\ ha^{-1}\ yr^{-1}$)* | Area 2002 (ha) | 2002 (%) | Area 2020 (ha) | 2020 (%) |
|---|---|---|---|---|---|---|
| 1 | Very low | 0–2 | 184,787 | 47.59 | 152,229 | 39.21 |
| 2 | Low | 2–5 | 55,104 | 14.19 | 70,430 | 18.14 |
| 3 | Moderate | 5–15 | 148,380 | 38.22 | 60,097 | 15.48 |
| 4 | Severe | 15–20 | 0 | 0.00 | 13,508 | 3.48 |
| 5 | Very severe | >20 | 0 | 0.00 | 92,007 | 23.70 |
| **Total** | | | **388,271** | **100.00** | **429,587** | **100.00** |

*Note: Original data reported in rai; values retained for consistency with official datasets.*

The results indicate a substantial shift from low and moderate erosion classes toward higher severity levels over time. Areas classified as severe and very severe erosion increased markedly in 2020 compared with 2002, reflecting intensifying erosion pressure in steep upland zones. This trend suggests growing vulnerability of the Man sub-watershed to accelerated soil loss, potentially driven by land-use changes and increased rainfall intensity.

**Table 2.** Soil erosion severity in the Phung sub-watershed (2001, 2013, and 2020)

| Class | Severity Level | Soil Loss (t $ha^{-1}$ $yr^{-1}$) | 2001 (%) | 2013 (%) | 2020 (%) |
|---|---|---|---|---|---|
| 1 | Very low | 0–2 | 42.37 | 44.32 | 55.80 |
| 2 | Low | 2–5 | 8.72 | 9.02 | 16.99 |
| 3 | Moderate | 5–15 | 7.13 | 17.26 | 10.87 |
| 4 | Severe | 15–20 | 1.66 | 1.46 | 2.69 |
| 5 | Very severe | >20 | 40.12 | 27.94 | 13.65 |
| **Total** | | | **100.00** | **100.00** | **100.00** |

Table 2. The Phung sub-watershed exhibited a general decline in areas classified as very severe erosion over time, accompanied by an expansion of low and very low erosion classes. These trends suggest improved land management effectiveness and gradual stabilization of erosion processes, likely associated with the adoption of soil and water conservation practices and vegetation recovery.

**Table 3.** Comparison of soil erosion severity between the Phung sub-watershed and the upper Pa Sak Watershed in 2013 and 2020

| Class | Severity Level | Soil Loss (t $ha^{-1}$ $yr^{-1}$) | Phung 2013 (%) | Upper Pa Sak 2013 (%) | Phung 2020 (%) | Upper Pa Sak 2020 (%) |
|---|---|---|---|---|---|---|
| 1 | Very low | 0–2 | 44.32 | 30.60 | 55.80 | 50.95 |
| 2 | Low | 2–5 | 9.02 | 32.55 | 16.99 | 11.21 |
| 3 | Moderate | 5–15 | 17.26 | 10.02 | 10.87 | 10.92 |
| 4 | Severe | 15–20 | 1.46 | 3.07 | 2.69 | 2.46 |
| 5 | Very severe | >20 | 27.94 | 23.76 | 13.65 | 24.46 |
| **Total** | | | **100.00** | **100.00** | **100.00** | **100.00** |

Table 3. Percentages represent the proportion of total watershed area falling within each soil erosion severity class derived from USLE-based raster classification and GIS spatial overlay analysis. Soil loss thresholds are expressed in tons per hectare per year (t $ha^{-1}$ $yr^{-1}$). The table enables comparison of spatial distribution and temporal shifts in erosion risk between the Phung sub-watershed and the Upper Pa Sak watershed for the years 2013 and 2020. Minor discrepancies in totals may occur due to rounding.

**Table 4.** Summary trend of high-risk erosion areas (severe + very severe)

| Watershed | Year | Severe (%) | Very Severe (%) | Severe + Very Severe (%) | Trend Interpretation |
|---|---|---|---|---|---|
| Man Sub-watershed | 2002 | 0.00 | 0.00 | 0.00 | Baseline low risk |
| | 2020 | 3.48 | 23.70 | 27.18 | ▲ Sharp increase |
| Phung Sub-watershed | 2001 | 1.66 | 40.12 | 41.78 | Historically high risk |
| | 2013 | 1.46 | 27.94 | 29.40 | ▼ Decreasing |
| | 2020 | 2.69 | 13.65 | 16.34 | ▼ Continued decline |
| Upper Pa Sak Watershed | 2013 | 3.07 | 23.76 | 26.83 | Relatively stable |
| | 2020 | 2.46 | 24.46 | 26.92 | Relatively stable |

Table 4. Percentages indicate the proportion of total watershed area classified as high-risk erosion zones, defined as the combined Severe (15–20 t $ha^{-1}$ $yr^{-1}$) and Very Severe (>20 t $ha^{-1}$ $yr^{-1}$) soil loss classes derived from USLE-based raster classification and GIS spatial overlay analysis. Trend interpretation summarizes temporal changes in the extent of high-risk erosion areas across monitoring periods for each watershed. Arrows denote increasing (▲) or decreasing (▼) trends. Slight discrepancies in totals may occur due to rounding.

Two representative study areas were selected as experimental sites to monitor soil loss from surface erosion processes over a three-year period. These sites represent the headwater environments of the Man and Phung watersheds, capturing contrasting landscape characteristics, slope gradients, land use patterns, and erosion susceptibility. As presented in Table 5, the experimental plots were designed to reflect spatial variability in upland agricultural fields and community forest systems. Field-based measurements of sediment loss provide empirical evidence that complements watershed-scale erosion modeling, allowing evaluation of localized erosion dynamics, temporal variation, and the effectiveness of site-specific land management and soil conservation practices. The results presented in the table contribute to a detailed understanding of micro-scale soil erosion behavior within headwater ecosystems.

Study Sites:

- ➢Ban Makkhaeng Yensira (Village No. 4, Koksathon Subdistrict, Dansai District, Loei Province) – Representative of the Man headwater area (8 experimental plots). (T1-T4)
- ➢Ban Nam Phung (Village No. 3, Pong Subdistrict, Dansai District, Loei Province) – Representative of the Phung headwater area (4 experimental plots). (T5-T8)

**Table 5.** Soil loss from experimental plots in representative villages of the man and Phung headwaters (three-year observation)

| Plot ID | Plot Location and Land Use Description | Average Slope (C°) | Erosion Severity Class | Soil Loss ($m^3$) Year 1 | Soil Loss ($m^3$) Year 2 | Soil Loss ($m^3$) Year 3 | Observed Erosion Characteristics |
|---|---|---|---|---|---|---|---|
| T1 | Agricultural plot, Ban Makkhaeng, Huai Dong Nguek (Man headwater tributary) | 40–50 | Very low | 0.10 | 0.05 | 0.05 | Minor surface runoff erosion |
| T2 | Agricultural plot, Ban Makkhaeng, Huai Tham Men | 35–50 | Very low | 0.05 | 0.05 | 0.05 | Stable soil surface |
| T3 | Agricultural plot, Ban Makkhaeng, Huai Tham Men | 35–50 | Severe | Sinkhole formation | 0.50 | Sinkhole | Localized soil collapse |
| T4 | Agricultural plot, Ban Makkhaeng, Huai Tham Men | 35–50 | Very severe | Large sinkhole | Sinkhole expansion | Further expansion | Progressive land instability |
| T5 | Agricultural plot, Ban Thung Thoeng (Phung headwater) | ~35 | Very low | 0.10 | 0.05 | 0.05 | Minor sheet erosion |
| T6 | Agricultural plot, Ban Nam Phung | 25–35 | Low | 0.10 | 0.25 | 0.20 | Seasonal runoff erosion |
| T7 | Agricultural plot, Ban Nam Phung | 25–35 | Low | 0.10 | 0.30 | 0.20 | Concentrated flow erosion |
| T8 | Community forest plot, Ban Nam Phung | 25–35 | Very severe | 1.00 | 1.00 | 1.00 | |

***Overall Soil Loss Patterns***: Across the three-year monitoring period, experimental plots exhibited substantial variability in soil loss magnitude and erosion mechanisms, reflecting differences in slope gradient, land use, vegetation cover, and subsurface stability.

- ➢ Very low erosion plots (T1, T2, T5) consistently showed minimal soil loss (≤0.10 $m^3$ per year), indicating that stable ground cover and moderate runoff control can effectively suppress erosion even on steep slopes (35–50°).
- ➢ Low erosion plots (T6, T7) demonstrated moderate fluctuation in soil loss (0.10–0.30 $m^3$), likely driven by seasonal rainfall variability and localized flow concentration.
- ➢ Severe and very severe plots (T3, T4, T8) exhibited nonlinear erosion behavior characterized by sinkhole formation, mass soil displacement, and persistent high soil loss (>1.0 $m^3$ annually in T8), highlighting the influence of subsurface instability and concentrated hydrological pathways.

***Spatial Differences between Headwater Zones:***

Man Headwater (Ban Makkhaeng Yensira)

- ➢ Plots T1 and T2 remained stable despite steep slopes (40–50°), suggesting that appropriate land management and vegetation cover can mitigate erosion risk.

- In contrast, plots T3 and T4 experienced severe erosion due to sinkhole development and progressive subsurface collapse, indicating geological vulnerability rather than surface slope alone as the dominant erosion driver.

***Phung Headwater (Ban Nam Phung)***

- Agricultural plots (T5–T7) showed low to moderate soil loss, reflecting relatively better soil structure and drainage stability.
- The community forest plot (T8) exhibited consistently high soil loss despite vegetative cover, implying that geomorphological conditions (e.g., shallow soils, fractured bedrock, or subsurface flow concentration) may override surface vegetation protection.

***Temporal Trends (Three-Year Observation)***

- Several plots demonstrated declining soil loss over time (T1, T5), possibly due to natural soil surface stabilization and minor conservation practices.
- Some plots showed fluctuating trends (T6, T7), indicating sensitivity to interannual rainfall variability.
- Severe plots exhibited progressive degradation rather than linear trends (T3, T4), reinforcing the need for structural interventions rather than solely agronomic measures.

The three-year experimental monitoring revealed strong spatial heterogeneity in soil erosion dynamics across representative headwater villages. Plots classified as very low erosion consistently recorded minimal soil loss ($<0.10$ $m^3$ $yr^{-1}$), even under steep slope conditions, highlighting the effectiveness of surface cover and stable land management practices. Conversely, plots exhibiting severe and very severe erosion displayed nonlinear degradation patterns dominated by sinkhole formation and mass soil displacement, indicating that subsurface geological instability plays a critical role beyond surface slope and vegetation cover.

Moderate erosion plots showed temporal variability associated with rainfall intensity and runoff concentration, underscoring the sensitivity of upland agricultural systems to climatic fluctuations. The contrasting responses between the Man and Phung headwater areas further emphasize the importance of site-specific conservation strategies rather than uniform watershed-wide interventions.

The following figures present representative photographs documenting three years of field observations (Year 3) of soil erosion processes and sediment yield across experimental plots T1–T8. These plots are located in two headwater areas of Dan Sai District, Loei Province: Ban Makkhaeng Yensira (Man watershed; T1–T4) and Ban Nam Phung (Phung watershed; T5–T8). The visual evidence captures contrasting erosion responses—including surface runoff patterns, sediment displacement, and sinkhole development—under varying slope conditions, vegetation cover, and conservation measures. These images provide qualitative support for the quantitative research analysis and illustrate the temporal evolution of land stabilization and erosion dynamics within their specific environmental and management contexts.

**Ban Makkhaeng Yensira**, Village No. 4, Koksathon subdistrict, Dansai district, Loei province

T1

T2

T3

T4

**Ban Nam Phun,** Village No. 3, Pong subdistrict, Dansai district, Loei province

T5

T6

T7

T8

## Discussion

### Comparative Dynamics of Soil Erosion under Different Watershed Contexts

The comparative analysis of soil erosion severity between the Phung sub-watershed and the Upper Pa Sak sub-watershed was not intended to determine which watershed experienced greater erosion intensity. Rather, the objective was to examine how internal biophysical conditions and land management interventions influence erosion dynamics under changing climatic conditions. Each watershed exhibits distinct controlling factors, including geological structure, slope gradient, soil depth and texture, land-use patterns, rainfall characteristics, soil moisture regimes, and geomorphological configuration. These interacting factors operate in a nonlinear manner, limiting direct one-to-one comparisons between watersheds (Tongdeenok, 2023).

A salient finding from this study is the substantial reduction in high-risk erosion areas (Severe + Very Severe classes) in the Phung sub-watershed between 2013 and 2020. The proportion of very severe erosion (>20 t $ha^{-1}$ $yr^{-1}$) declined markedly, indicating a tangible improvement in landscape stability following the intensified implementation of soil and water conservation measures. These measures included reduced tillage practices, vegetative cover enhancement, agroforestry systems, and community-based watershed rehabilitation. Mechanistically, such interventions increase surface roughness, enhance soil aggregate stability, reduce raindrop impact energy, and improve infiltration capacity, thereby decreasing surface runoff and sediment transport.

These findings are consistent with empirical and modeling studies in Thailand and comparable tropical watersheds, which demonstrate that vegetative cover management and conservation-oriented land use can significantly reduce soil erosion rates and sediment yield (Phomcha et al., 2012; Sirikaew et al., 2020). Similar conclusions have been reported for upland agricultural landscapes, where conversion from conventional tillage to conservation agriculture improves soil structural resilience and reduces erosion susceptibility (Kongkhiaw et al., 2021).

In contrast, the Upper Pa Sak sub-watershed exhibited relatively stable but persistently high proportions of very severe erosion areas between 2013 and 2020, with a slight increase in high-risk zones. This pattern suggests that conservation interventions in this watershed may be insufficient to offset ongoing erosion drivers, such as land-use intensification on steep slopes, limited vegetative buffering, and fragmented institutional coordination. Previous watershed-scale assessments in Thailand similarly indicate that without sustained and spatially coherent conservation strategies, erosion risk tends to remain elevated even when isolated mitigation measures are implemented (Tongdeenok, 2023).

The divergent trajectories observed between the two watersheds highlight the importance of adaptive governance and locally appropriate intervention strategies. While the Phung sub-watershed demonstrates the potential effectiveness of integrated conservation practices, the Upper Pa Sak watershed underscores the risks associated with delayed or uneven implementation. These contrasting cases provide valuable opportunities for cross-watershed learning and policy transfer.

**Climate Variability, Rainfall Extremes, and Implications for Erosion Risk**

Climate projection analysis based on Global Climate Models (GCMs) downscaled using Regional Climate Models (RCMs) for the Dansai District indicates a consistent warming trend accompanied by increasing climate variability (Jirasorn et al., 2017). Maximum temperatures are projected to rise steadily, while minimum temperatures show an even stronger upward trend, implying higher evapotranspiration demand, increased soil moisture stress, and greater vulnerability of rainfed agricultural systems to drought conditions.

Rainfall projections reveal substantial interannual variability rather than a consistent increase in total precipitation. Although certain years may experience exceptionally high rainfall associated with flood and landslide risks, the long-term trend suggests shortening rainy seasons and increasing rainfall concentration within shorter time windows. Such rainfall concentration significantly amplifies erosion processes by increasing rainfall erosivity (R-factor in USLE), surface runoff velocity, and sediment transport capacity.

Historical climate observations from Thailand further support this pattern, showing relatively stable annual rainfall totals but a shift in seasonal distribution toward late rainy-season concentration (Land Development Department, n.d.; Thai Meteorological Department, 2025). Field observations during recent years similarly indicate shorter rainy seasons combined with higher rainfall intensity. These climatic dynamics interact with watershed characteristics to intensify erosion mechanisms through stronger raindrop impact, reduced soil infiltration capacity during extreme events, and vegetation stress during prolonged dry periods.

Previous modeling studies in Thailand have demonstrated that even modest increases in rainfall intensity can significantly elevate predicted soil loss when combined with steep slopes and shallow soils (Sirikaew et al., 2020). Therefore, climate variability acts as a critical amplifying factor that can either undermine or enhance the effectiveness of conservation interventions, depending on land management resilience.

**Role of Participatory Governance and Ecosystem-Based Adaptation**

A distinctive contribution of this study lies in its application of Participatory Research and Development (PR&D) and Participatory Action Research (PAR) frameworks. The observed improvements in the Phung sub-watershed cannot be attributed solely to biophysical interventions but also reflect strengthened community engagement, shared learning, and local ownership of conservation practices. Participatory approaches enhance the legitimacy, continuity, and adaptive refinement of interventions, particularly in complex upland socio-ecological systems (Sengtaweesuk et al., 2025). Moreover, the integration of ecosystem-based measures—such as riparian buffer restoration, bamboo stabilization, and agroforestry systems—aligns with emerging evidence that nature-based solutions can simultaneously reduce disaster risk, enhance ecosystem services, and strengthen climate resilience (Thai–German Cooperation, 2023). These approaches also complement spatial planning instruments, such as geo-social mapping and participatory watershed planning, which enable communities and agencies to align land management decisions with ecological constraints.

***Policy Implications and Limitations***

From a policy perspective, the contrasting erosion trajectories between the Phung and Upper Pa Sak watersheds emphasize the need for context-specific, long-term conservation strategies supported by institutional coordination and community participation. Scaling successful practices from the Phung watershed to other vulnerable basins may enhance regional resilience to soil degradation and climate extremes. However, several limitations should be acknowledged. Soil erosion severity was estimated using USLE-based spatial modeling and GIS raster classification, which are sensitive to rainfall data resolution, land-use classification accuracy, and parameter calibration. Consequently, the results should be interpreted as spatial risk assessments rather than exact measurements of on-site soil loss (Kongkhiaw et al., 2021; Sirikaew et al., 2020). Future research should integrate higher-resolution climate datasets, sediment monitoring, and long-term experimental plots to strengthen predictive reliability.

Overall, the combined evidence underscores the necessity of adaptive, participatory, and ecosystem-based watershed management approaches to sustain soil resources, protect agricultural productivity, and enhance climate resilience in upland regions.

**Micro-scale Soil Erosion Dynamics in Headwater Experimental Plots**

The three-year field monitoring of experimental plots in representative headwater villages revealed strong spatial heterogeneity in soil erosion dynamics, driven by interactions among slope gradient, land use, vegetation cover, hydrological pathways, and subsurface geological conditions. Plots classified as very low erosion (T1, T2, and T5) consistently recorded minimal soil loss (<0.10 $m^3$ $yr^{-1}$), even on steep slopes exceeding 35–50°, indicating that stable ground cover and appropriate land management can effectively suppress surface erosion (Morgan, 2005; Lal, 2015).

In contrast, severe and very severe plots (T3, T4, and T8) exhibited nonlinear degradation characterized by sinkhole formation, mass soil displacement, and progressive land instability. These patterns suggest that subsurface geomorphological vulnerability—such as shallow soils, fractured bedrock, and preferential flow paths—can dominate erosion processes beyond surface slope and vegetation effects, consistent with findings in tropical upland environments (Bryan & Jones, 1997; Valentin et al., 2005; Sidle et al., 2006).

Moderate erosion plots (T6 and T7) showed interannual variability linked to rainfall intensity and runoff concentration, reflecting the sensitivity of upland agroecosystems to climatic variability (Nearing et al., 2017; IPCC, 2021). The contrasting responses between the Man and Phung headwaters emphasize that erosion control strategies must be site-specific rather than uniformly applied at the watershed scale. While some steep agricultural plots remained stable due to effective management, adjacent plots experienced severe degradation driven by geological constraints.

Overall, the experimental evidence confirms that micro-scale field observations are essential for validating watershed-scale erosion models and for designing adaptive soil and water conservation strategies under climate change. Effective mitigation requires integrating surface management practices with targeted structural interventions in geologically sensitive areas (Renard et al., 1997; FAO, 2017; Alewell et al., 2019).

## Recommendations

**Implement Risk-Based Spatial Zoning for Soil Erosion Management:**

Soil conservation policies should shift from slope-based criteria toward integrated risk-based spatial zoning that incorporates geological structure, soil depth, subsurface hydrology, land-use intensity, and erosion history. The experimental plots revealed that severe erosion and sinkhole development occurred even under vegetated conditions, indicating that subsurface instability can override surface protection measures. High-resolution geospatial risk mapping should therefore guide prioritization of conservation investments, land-use regulation, and infrastructure placement in headwater regions.

**Integrate Structural Stabilization with Nature-Based Solutions in High-Risk Areas**

In geologically vulnerable zones, conservation strategies should combine engineering stabilization measures (e.g., subsurface drainage control, reinforced terraces, contour barriers, and flow diversion structures) with biological approaches such as agroforestry, perennial vegetation, and ground cover management. While vegetative practices effectively reduced erosion in stable plots, severe erosion plots exhibited nonlinear degradation requiring structural reinforcement. Integrated hybrid solutions can enhance slope stability, reduce concentrated runoff, and improve long-term ecosystem resilience.

Strengthen Community-Based Monitoring and Adaptive Watershed Governance

Localized plot monitoring captured erosion dynamics and threshold behavior that are not fully detected by watershed-scale models. Institutionalizing community-based monitoring networks and linking them with GIS platforms can enhance early-warning capacity, validate erosion models, and support adaptive decision-making. Embedding erosion risk information into geo-social mapping and participatory planning processes will strengthen stakeholder ownership and improve long-term maintenance of conservation interventions.

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**Research Article**

# Climate change adaptation education as a tool for biodiversity conservation and sustainable agricultural systems

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**Abstract**

Adaptation to climate change is a set of measures that need to be implemented to protect biodiversity and especially natural ecosystems and to ensure that greenhouse gases in the atmosphere remain at normal levels. In societies where individual awareness of climate change and nature cannot be achieved, the applicability and impact of adaptation strategies remain limited. Practical training that includes climate- and environmentally friendly behaviors positively impacts climate change awareness. Increasing awareness of the impacts of climate change can lead to success in adapting to it. With this study, it is aimed to contribute to the studies on adaptation to climate change. This article aims to offer suggestions on what can be done to reduce the negative effects of changes in climate parameters that alter the life cycle of all living things on biodiversity and human life. Raising public awareness is crucial for combating the effects of climate change. To prevent the negative impacts of climate change, which is becoming increasingly evident worldwide, countries must make joint decisions and act together. Furthermore, to reduce the negative effects of global warming resulting from climate change and to enable them to take the necessary precautions, comprehensive education programs must be developed and implemented for all individuals.

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## Introduction

Climate change refers to long-term changes resulting from the disruption of the natural balance of climate systems worldwide due to human activities. Climate change is associated with an increase in the concentration of greenhouse gases in the atmosphere and the resulting rise in average global temperatures (Kurnaz, 2023). Global climate change is one of the most important environmental and social problems affecting the planet and living things. The presence of greenhouse gases such as carbon dioxide ($CO_2$), methane ($CH_4$), diazot monoxide ($N_2O$) and ozone ($O_3$) in the atmosphere causes the atmosphere to retain more rays from the Sun. This effect causes more heat to rise in the atmosphere and the Earth to warm up more (IPCC, 2023; Akgün and Önder, 2025).

2024 was the warmest year on record for global temperatures dating back to 1850. The global average temperature for 2024 was 15.10°C. This was 0.12°C higher than the previous highest annual value in 2023. Besides 2024 was the first year in which the global average temperature was 1.5°C above pre-industrial levels. Keeping the global average temperature at 1.5°C was the threshold set by the Paris Agreement to significantly reduce the risks and impacts of climate change. Multiple global records were broken for greenhouse gas levels and both air temperature and sea surface

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temperature, contributing to extreme events such as floods, heat waves and wildfires (Copernicus, 2025). Scientists state that the Earth's temperature has increased enough in the last 50 years to affect human life. If no action is taken, they predict that the Earth's temperature will increase by approximately 2°C by the end of the 21st century. In addition to the increasing warming of the Earth's climate, it is estimated that the average surface temperature of the Earth will increase by 1.4-5.8°C between 1990 and 2100 (Turan, 2014; Kırpık et al., 2022). If global warming is kept below 2°C, only less than 2% of ecological communities worldwide and more than 20% of their component species are expected to experience sudden losses due to climate change. However, this risk increases rapidly as the level of warming increases, threatening 15% of species in the event of a 4°C warming. In addition, it has been determined that these risk levels are similar between protected and unprotected areas (Trisos et al., 2020; Şimşek and Kurtuluş, 2025). These findings indicate that sudden and severe biodiversity losses caused by climate change pose an imminent threat (Şimşek and Kurtuluş, 2025).

The concept of biodiversity refers to a broad field of study and research within the science of biology. In this context, it refers to the diversity of living beings regardless of their origin. It includes terrestrial, marine, oceanic and other aquatic ecosystems, ecosystem communities, intraspecific, interspecific and inter-ecosystem diversity (United Nations, 1992; Kurt, 2017). Prioritizing biodiversity and using ecosystem services that enable people to adapt to the negative effects of climate change can be described as a nature-based solution (Kara and Yereli, 2022). WWF (2020) defines nature-based solutions as ecosystem conservation, management and/or restoration interventions that can reduce the long-term impacts of climate change, manage expected climate risks to nature, have co-benefits for people and biodiversity, and provide measurable positive climate adaptation and/or mitigation (Kaçmaz, 2021). Flooding is the event of areas that would not normally be flooded being submerged due to above-normal flow and level rise in a river. It is an adverse event that occurs depending on the geological conditions, topographical features and existing hydrological and climatic conditions of the regions. Floods are one of the most common types of disasters, usually occurring as a result of excessive runoff from dry lands. Extreme heavy rainfall, rapid melting of snow cover, tsunamis in coastal areas and storms originating from tropical cyclones are among the causes of floods. (Republic of Türkiye Ministry of Forestry and Water Affairs, General Directorate of Water Management, 2017; Süzgenli, 2024). Construction should be avoided in areas with a high risk of flooding. The risk of flooding can be reduced by preserving and increasing green spaces. Afforestation can be carried out, especially on sloping hillsides (Süzgenli, 2024). Ecological benefits provided by nature-based solutions include regulating water flow and cycle, preventing drought, water scarcity, floods and inundations, improving water, soil and air quality, biological treatment, preventing soil loss, reducing disaster risk, protecting and supporting biodiversity, capturing and storing carbon, providing disease and pest control, restoring degraded areas and reducing noise. Nature-based solutions in coastal ecosystems and coastal areas provide protection of coastal ecosystems, reducing coastal floods and inundations, preventing coastal erosion, sequestering and storing carbon, protecting biodiversity and creating recreational opportunities (Coşkun Hepcan, 2022).

Agricultural production is directly affected by changes in climate parameters such as temperature, rainfall and humidity; in other words, by climate change. The increase in summer and winter temperatures in some parts of the world due to climate change will lead to decreases in agricultural production because plants cannot adequately meet their chilling requirements. Breeding programs should be increased to develop drought-resistant varieties with low chilling requirements. In some fruit species, under conditions of extreme cold, defoliation, browning of shoots, freezing of trunks, bark cracking and tree desiccation may occur. Depending on the severity of the cold, this can result in the death of the tree. The increase in temperatures in some northern regions of the world will positively impact agricultural production by creating suitable climatic conditions for the cultivation of new species and varieties. Decreased rainfall will negatively impact yields, leading to a drop in agricultural income. Since flower bud formation in fruits begins the previous year, reduced rainfall affects the yield and quality of the following year. Hail damage, depending on the phenological stage of the affected plant, can cause flower and fruit drop, loss of fruit quality and diseases due to wounds on the plant. Excessive rainfall can cause cracking in some fruit types, diseases in the root zones of plants due to rising groundwater levels and yield reductions due to flower drop (Gökkür, 2019).

**Figure 1.** Excessive rainfall can result in peel cracking in pomegranate fruit (Original photograph by Gökkür, 2023)

Excessive humidity during the pollination period of some fruit trees prevents pollination by sticking the pollen grains together. Hot and drying winds during this period dry out the stigma, reducing pollination and fruit formation. In some fruit species, the effect of heat decreases in high humidity, but a suitable environment for some diseases is created. Insufficient relative humidity and dry conditions negatively affect flowering and the development of flowers into fruit (Ayaz and Varol, 2015; Gökkür, 2019). It is observed that diseases and pests, which are increasing in many plant species due to climate change, negatively affect the yield and quality of agricultural production (Gökkür, 2019).

The impacts of climate change on agriculture can impact food security and international trade. Because agriculture is an economic activity that not only provides food but also significantly impacts economic balances. For example, reduced production can lead to increased product prices, higher consumer prices, increased imports and decreased exports. Moreover animal production is directly or indirectly affected by climate change. Rising temperatures can disrupt the balance between heat production and utilization in animals. This can lead to decreased pregnancy rates, increased abortions, increased mortality, decreased feed intake, decreased feed conversion, changes in live weight and decreased milk and meat production. Changes in animal production also impact costs (Dellal and McCarl, 2007; Dellal, 2018; Dellal et al., 2020). Moreover the production and distribution of energy are affected by factors such as the depletion of water resources due to climate change. Water-dependent renewable energy sources, such as hydroelectric power plants, are directly impacted by falling water levels. Furthermore, high temperatures increase energy demand and can strain electricity infrastructure (Columbia Climate School, 2022; Keskinden, 2024).

Adaptation means the emergence of a situation that is different from the norm and the ability to adapt to the new situation. Climate change is the unusually frequent changes in climate parameters. In fact, as the definition suggests, climate change calls for adaptation. Because climate change impacts biodiversity, land and marine ecosystems, water resources, the energy sector, agriculture, fisheries, the food sector, the manufacturing industry, transportation, tourism and public health, adaptation activities must be determined separately for each sector or area. Adaptation also means managing risks effectively.

Mitigation and adaptation strategies are widely used in combating climate change. The mitigation strategy is based on directly reducing carbon emissions, which are the main source of climate change; It includes practices such as capturing and storing carbon, reducing energy demand, reducing vehicle demand by providing recreation opportunities in the city and its immediate vicinity and enabling food production in the city and its immediate vicinity (BUSECAP, 2017). Moreover the creation of green areas increases the recreation and tourism potential of regions. It contributes to increasing the level of knowledge and awareness of urban residents and visitors on climate change and biodiversity. Creating blue-green infrastructure components specific to local conditions, including nature-based or hybrid solutions such as rain gardens, green walls, roof gardens, rain ditches, urban orchards, urban parks, gardens, green corridors, stream corridors, flood parks, etc. in urban micro-watersheds increases the climate resilience of urban systems. Designing a system that resembles the functioning of the natural system in micro-watersheds reduces the risk of water and high temperature-related disasters (Coşkun Hepcan, 2022).

Adaptation to climate change has a structure that varies and diversifies according to urban and local conditions and sectors. In order to adapt to the effects of climate change, it is necessary to conduct "impact analysis" studies in the first stage on sectors that may be negatively affected by climate change, such as water resources, agriculture and food security, public health, natural ecosystems and biodiversity, coastal regions. A "vulnerability/risk assessment" should be conducted regarding the potential water shortages, droughts, desertification, increased disasters, decreased agricultural production, deterioration in food security and public health, degradation of terrestrial and marine ecosystems, negative impacts on energy, tourism and fisheries and threats to coastal areas due to sea level rise. Adaptation action planning must be integrated into sectoral development plans at the national, regional and local levels (Talu, 2021).

Although experts have been studying global warming, biodiversity loss, epidemics or infectious diseases and economic and social impacts for years, societal measures to prevent warming remain insufficient. Changes in economic growth, markets, international trade and economic policies resulting from climate change have different consequences for economies depending on their level of development. It is known that less developed countries will be more affected by climate change than other countries and their development and economic growth rates are negatively impacted. It is predicted that if global warming cannot be prevented, societal adaptation will be difficult (Özüşen, 2023).

**Objectives**

Climate change constitutes one of the greatest challenges facing humanity in the last century (Swim et al., 2011; Özbay and Alcı, 2021). Short-term and long-term effects of climate change may be accompanied by trauma, anxiety, fear, worry and depression (Cianconi et al., 2020; Doherty and Clayton, 2011; Clayton et al., 2017; van der Linden, 2017; Özbay and Alcı, 2021).

Climate change education is related to environmental education, sustainable development education and disaster risk reduction education (Barak, 2018). In order for students to develop behaviors that will help combat climate change, it is primarily necessary to increase their contributions to solving environmental problems. According to Mochizuki and Bryan (2015), climate change education addresses content-based information such as climate, deforestation, habitat loss, water cycle, soil erosion, air pollution and other content-based information, while also addressing environmental concerns such as reducing carbon consumption, promoting low-carbon development, reducing deforestation through sustainable forest management and improving water and waste management, in order to raise students' awareness (Barak, 2018).

Early childhood is considered a critical stage for the permanent establishment of any behavior. Educating children about ecological sustainability, ecosystems, biodiversity and climate change appears to be the most effective way to solve environmental problems (Celiloğlu, 2023). When the literature is considered, it is a fact that young children are the future individuals who will realize the plans and solutions for climate change. They should be given opportunities to realize this change. It's safe to say that if children are provided with the necessary educational environments, they can take positive action against climate change, starting with their immediate surroundings (Duran, 2023). Communicating scientific knowledge to a wide audience, minimizing the impacts of global climate change through cooperation among all segments of society and creating hope that it is not too late to take action are key tasks for future decision-makers in combating global climate change (Yüce Yörük and Varer Akpınar, 2023).

The World Conservation Strategy is a strategy created in 1980 by the International Union for Conservation of Nature, the United Nations Environment Programme and the World Wildlife Fund (WWF). This strategy aims to provide a framework for the conservation and sustainable management of the natural environment on a global scale. The World Conservation Strategy is designed to promote international cooperation and action on environmental protection and sustainable resource management and has developed an ecological approach and strategies primarily focused on the protection of the physical environment (Bozlağan, 2005; Aytaç, 2023).

**The strategies outlined within this framework are grouped around four main objectives** (Bozlağan, 2005; Aytaç, 2023):

**Biodiversity conservation:** The strategy emphasizes the importance of conserving biodiversity and proposes various conservation measures to prevent habitat and species loss (Bozlağan, 2005; Aytaç, 2023). Pollinating insects play a crucial role in the functioning of ecosystems, the maintenance of biodiversity and agricultural production. Various practices in industrial agriculture and the excessive use of chemicals are reducing the densities of pollinating insects and bringing many species to the brink of extinction. To protect biodiversity threatened by climate change, it is necessary to create suitable habitats for pollinators in the design of cities and the planning of industrial areas, and to reduce the use of chemical pesticides in agriculture (Demir Özden and Ünver, 2023).

**Sustainable management of natural resources:** The sustainable use and management of natural resources is a key component of the strategy. This promotes sustainable practices in sectors such as forestry, water management, fisheries and agriculture (Bozlağan, 2005; Aytaç, 2023).

**Control of environmental pollution:** The strategy proposes controlling pollution and minimizing environmental impacts. It includes measures against water, air and soil pollution (Bozlağan, 2005; Aytaç, 2023). Some agricultural producers who throw pesticide containers into irrigation canals are causing pollution of water and soil resources. To prevent this type of environmental pollution, regulations should be prepared and implemented that include deterrent measures such as the cancellation of agricultural subsidies (Gökkür, personal communication, November 20, 2025).

**Sustainable development:** The World Conservation Strategy aims to strike a balance between environmental conservation and development. It emphasizes the environmental and social dimensions of sustainable development (Bozlağan, 2005; Aytaç, 2023). In order to achieve sustainable development, attention must be given to the protection of nature in every activity undertaken.

The aim of climate change education is to inform communities about the impacts of climate change, its causes and ways to combat it. Besides the main objectives of climate change adaptation training are to increase the capacity of societies to cope with climate change, to raise knowledge and awareness on this issue, and to determine the activities that will be least affected by the negative effects of climate change. Achieving success in combating climate change requires the development and implementation of adaptation and mitigation strategies. Training programs aimed at combating climate change should be designed using a lifelong learning approach, encompassing all age groups from children to adults. These programs should be tailored to individuals' ages and knowledge levels, aiming to enhance their awareness and understanding.

## Teaching Methods on Climate Change

The key actors in delivering climate change education to the public are academics, teachers and trainers. To raise awareness about climate change in society, individuals of all age groups need to receive training at different levels. Educational programs in the field of climate change should include understandable and regularly updated educational materials suitable for all age groups. This approach will increase the effectiveness of adaptation processes to the negative impacts of climate change.

Teachers play a key role in climate change education. Therefore, teachers need to constantly update their knowledge of climate change in light of new scientific developments and recent reports. In particular, teachers need to improve their knowledge of solutions to combat climate change (within the scope of mitigation and adaptation) and develop their pedagogical content knowledge on how to incorporate these solutions into their lessons. For this reason, more emphasis should be placed on solutions to combat climate change in teacher training (Parmak and Karaarslan Semiz, 2024).

Siron, et al. (2021), in their study aiming to identify the perspectives of teachers and pre-service teachers to promote climate change awareness in early childhood education, found that there was no significant difference between teachers and pre-service teachers in terms of climate change awareness. Participants indicated how they would develop children's awareness using media, learning resources, methods, indoor and outdoor play activities and how they would evaluate the learning process to implement climate change awareness in early childhood education (Duran, 2023).

Before explaining the causes and consequences of climate change and answering their questions, children should be taught how nature and ecosystems work and how everything in nature is interconnected, limited and harmonious. We should encourage children to notice and be curious about the natural processes that make life possible. The information and words given should be chosen according to the children's personality traits. For example, it would not be helpful to talk about negative scenarios with an introverted child who may experience anxiety. Be aware of children's developmental stages and consider their emotional and social development characteristics (Anonymous, 2025).

In terms of climate change, the necessary action is to reduce greenhouse gas emissions immediately and to near zero. Since this does not seem possible at the moment, we need to take advantage of adaptation opportunities to cope with the problems that will arise (Kurnaz, 2023).

**Educational Approaches and Practices to Improve Climate Change Adaptation for Children**

- The primary goal should be to get children to spend time in nature, play, wonder, observe and love nature. Children should be given opportunities to protect and love living things.
- Planting seeds, watering flowers, feeding stray animals and preparing nutritious food for birds with children contributes to raising awareness of ecological responsibility in the fight against climate change through interaction with nature.
- Observing weather, seasons and climate can provide a good foundation for children to understand and become aware of climate change. Instructors should ask them questions like, "What happens in nature in different seasons? How do trees change? What do birds, insects, butterflies and bees do?" during their lessons.

**Figure 2.** Nature-based observation plays a significant role in enhancing children's understanding of climate change (Original photograph by Gökkür, 2025b).

Talks should be made with children about how they feel when they encounter or have experienced extreme heat waves, hailstorms, or floods. Children should be told that it is normal to feel scared, anxious and sad after such events caused by climate change.

Raising awareness among the public, especially students, about preventing climate change is crucial for a livable world. Therefore, it is important that individuals, society and the state all have responsibilities in preventing climate change and show sensitivity in this regard (Uzun, 2021).

**Key Objectives of Climate Change Adaptation Training Targeting All Age Groups**

**Raising Awareness of Climate Change**

In recent years, increasing industrialization, the decrease in forests and green areas, the use of fossil fuels and the increase in environmental pollution have increased global warming (IPCC, 2023; Akgün and Önder, 2025). There is an important relationship between climate change education and environmental education. When the goals of these disciplines are examined, it is seen that they have common aspects. Therefore, the use of environmental education approaches in climate change education increases the impact of climate change education (Barak, 2018; Darbaş and Yıldırım, 2024). Climate change education has been accepted as an approach that aims to develop students' climate change awareness in primary and secondary schools. Climate change education has an important place in education provided in schools, aiming to improve the education system (Oversby, 2015; Darbaş and Yıldırım, 2024). As can be seen from the conferences organized by the United Nations and the reports they have published in the last 30 years, climate change is the most important environmental issue faced by every individual (Barak, 2018). It is seen that some countries have included climate change education in their curricula upon the call of the United Nations (Barak, 2018; Darbaş and Yıldırım, 2024).

In combating climate change, people's behavioral changes in many areas from water saving to energy consumption, from waste management to reducing unnecessary consumption habits are aimed to be gained with this training and it is designed to direct individuals to search for solutions on issues such as saving energy, gaining low-carbon living habits with less consumption and protecting nature. Consequently, climate change education plays a significant role in raising people's awareness for a sustainable life. Participants should be taught the scientific basis of climate change, its impacts and the resulting problems. Most importantly, past and present perceptions of climate change should be discussed. Awareness training should explain the causes and effects of climate change and why we must act quickly to combat it.

**Training content**

It should be explained that climate change has diverse impacts at the local, regional and global levels, and that these impacts alter food production and living spaces. To raise awareness, the training should cover the definition of climate change, the relationship between greenhouse gases and climate change, climate parameters, causes of climate change, biodiversity loss caused by global warming, depletion of water resources, effects of climate change, disasters caused by climate change, sea level rise and its effects on coastal areas, negative impacts on food production and future scenarios related to climate change. Participants should also be informed about measures that can be taken to prevent climate change.

**Developing Adaptation Strategies**

Information can be shared with participants about adaptation strategies they can adopt individually and collectively in response to climate change. For adaptation, topics such as the implementation of new methods in agriculture, water management, energy efficiency and sustainable transportation can be covered in training.

Strategies should be developed to increase resilience and reduce vulnerability to climate change. Growing drought-resistant crops, construct weather-resistant constructing roads, buildings and bridges suitable for changing climate conditions are some examples of efforts that can be made to adapt to climate change (Anonymous, 2025). Furthermore, trees can be used as windbreaks to reduce wind speed around buildings. In winter, reducing wind speeds, especially cold northerly winds, can provide significant energy benefits. Green spaces help offset the formation of urban heat islands by cooling the regional microclimate through shading and evaporation, thus reducing the energy needed to cool buildings during the hot season. Planting trees (more than any other type of vegetation) is the best way to combat urban heat islands because trees have a higher potential to cool the climate and reduce the urban heat island effect and carbon dioxide ($CO_2$) levels. Municipalities should create a more livable urban environment for all citizens by planting and maintaining city trees (Özkaplan Yörüklü, 2021).

One of the most significant causes of climate change is increasing greenhouse gas emissions. Ecological agriculture practices reduce greenhouse gas emissions, increase soil carbon stores and water retention capacity, and improve crop yield and profitability. This production system takes into account the functioning of the natural cycle between soil, plants, animals and humans. The ecological agriculture philosophy refers to a farming culture described as a "closed system," where inputs are obtained as much as possible from within the farm or its immediate surroundings and the farm ensures its self-sufficiency (Çelik et al., 2017). Ecological farming practices can help mitigate the negative effects of climate change and contribute to the conservation of natural resources.

In agricultural production, the selection of drought-tolerant species and varieties with low water requirements, the implementation of efficient irrigation methods, the use of water harvesting techniques and practices aimed at conserving soil moisture through mulching with plant residues (e.g., leaves) are among the activities considered within the framework of climate change adaptation. In addition the transition to pressurized irrigation systems, aimed at ensuring sustainable agricultural productivity and efficient use of water resources, is among the key measures for adapting to climate change.

**Understanding Climate Change through Technology-Based Education**

Productivity in the agricultural sector is shaped by many factors, including plant characteristics, soil structure and climatic conditions. Therefore, both short-term weather forecasts and long-term climate data analysis are of great importance in planning agricultural activities. Agricultural decision-makers try to optimize production processes by considering daily and weekly weather forecasts along with long-term climate data. Daily agricultural practices are planned and implemented according to meteorological parameters such as cloud cover, probability and duration of precipitation, wind speed and direction, and minimum and maximum temperature values. These short-term forecasts offer significant advantages to producers in terms of reducing production costs and preventing potential crop losses. Weekly forecasts are particularly helpful in creating agricultural work programs for 5 to 7 days (Uslu et al., 2025).

Satellite imaging systems, supported by artificial intelligence (AI)-based sensor technologies, enable early detection of diseases and pests, optimize pesticide use in agriculture and slow down the rate of soil and water pollution. This training should provide information on technologies used to combat climate change. For instance smart agriculture techniques, vertical farming and hydroponic systems, projections on climate change should be explained.

***Virtual training games and simulations*:** Participants are expected to develop solutions for various climate change scenarios in virtual environments. Educational games and seminars will facilitate understanding of topics such as virtual modeling in agricultural production planning and combating the negative impacts of climate change.

***Pre-Developed Projects for Climate Change Adaptation:*** In the fight against climate change, tools such as life cycle assessment, environmental product declaration and carbon footprint are crucial for businesses. These tools allow businesses to measure and report their activities that contribute to climate change (Fet and Knudson, 2021; Keskinden, 2024). In particular, the carbon footprint helps businesses reduce their impact on climate change by tracking greenhouse gas emissions generated in their production processes. In the fight against climate change, it is critical that businesses not only fulfill legal obligations but also assume environmental responsibilities for the future (Keskinden, 2024). Participants should be informed about projects related to climate change. Fieldwork can be conducted by visiting project-supporting institutions and organizations and observations can be made during some projects.

The training content includes environmentally friendly agricultural technologies (such as solar energy), water management, irrigation systems and water use efficiency. Farmers and businesses using modern irrigation systems should be visited. Photovoltaic and agrivoltaic systems should also be introduced through presentations.

**Risk Management and Crisis Preparedness**

***Disaster preparedness*:** Disaster risks have a significant impact on sustainable development and can lead to negative effects on lives and livelihoods (Tazegül Bekci and Şahinöz, 2024). The risks of recurrence of disasters encountered in the past, such as drought, floods, storms, hail and strong winds, should be identified and adaptation strategies should be developed to adapt to disasters. Training should be provided on how to prepare for natural disasters (floods, droughts, hail, storms, etc.) and other climate-related crises.

To be prepared for floods caused by excessive rainfall, some of the adaptation activities that need to be taken include creating flood risk maps and developing early flood warning systems and establishing safe housing areas in surrounding regions for emergencies (Talu, 2021). Increasing forest and tree cover contributes to disaster risk reduction. Forests play a critical role in combating climate change because they capture carbon dioxide. Since the carbon dioxide captured by trees will be released into the atmosphere during a fire, measures must be taken to prevent forest fires.

Building disaster resilience, especially in addressing climate-related risks requires cooperation among local, national and international stakeholders to achieve successful outcomes. Action is needed to prevent new risks from climate change, reduce existing vulnerabilities and achieve the goals of the Sendai Framework, the Paris Agreement and the Sustainable Development Goals (Tazegül Bekci and Şahinöz, 2024). Training can be provided on the importance of early warning systems and crisis management for emergencies that may arise from climate change.

**To Offer Suggestions for Ensuring the Sustainability of Life**

Nature-based solutions make significant contributions to mitigating the negative impacts of climate change through the conservation, restoration and sustainable management of ecosystems. Nature is, in many cases, the most effective insurance policy. Nature-based solutions offer opportunities to restore cities' broken relationship with nature. Natural ecosystems are living systems and are constantly under the influence of changing climatic and environmental conditions. These impacts, of varying severity, lead to disruptions and changes in ecosystems. Natural systems are designed to survive and have the ability to heal (repair) themselves when damaged. This ability provides resistance/resilience to the effects that cause disruption in natural systems. The ability of natural systems to heal and repair themselves is of great importance in the face of increasing problems with climate change. Nature-based solutions can be natural (natural ecosystems), semi-natural (hybrid solutions - swales, semi-natural stream corridors, coastal embankments, etc.) or human-created cultural solutions (roof gardens, green walls, etc.) (Coşkun Hepcan, 2022). Green belts should be created in urban areas. Bringing biodiversity to urban and industrial areas with green roofs, balconies and gardens will reduce the negative effects of heat islands in cities.

***Low carbon footprint:*** Participants should be trained on reducing carbon emissions, making energy consumption more efficient, recycling and using renewable energy. It is important to properly inform people about carbon taxes in order to achieve social consensus in the fight against climate change. Additional taxes and trade restrictions can be imposed on companies that emit excessive amounts of carbon.

***Raising awareness about the importance of investing in the green economy:*** Dependence on the use of fossil fuels has made the green transformation in energy a necessity. In industrialized cities, the use of green energy shapes sustainability policies due to its environmental and economic benefits. The use of green energy supports sustainable practices by reducing carbon emissions (Wang, 2021; Keskinden, 2024). Furthermore green roofs and walls reduce energy consumption in buildings, thus reducing the urban heat island effect. They also contribute to energy efficiency by reducing energy consumption in the summer months. In winter months, they can reduce heating costs by increasing building insulation (Campiotti et al., 2013; Keskinden, 2024). Information can be provided about green employment opportunities, environmentally friendly initiatives and projects.

**Providing Information on Policies and Legal Frameworks**

Deficiencies in legal and administrative regulations to combat climate change should be addressed. In addition The media, identified as a player as influential as local governments in the implementation of climate change policies, should assume greater responsibility for raising public awareness (Albayrak and Atasayan, 2017). Participants should be informed about national and international climate change agreements, such as the Paris Agreement and their impacts on social and economic life. Additionally, information can be provided regarding strategies developed by municipalities and local authorities to mitigate and adapt to climate change.

**Awareness**

People can be informed about actions they can take to combat climate change. Climate change education for younger generations can help them adopt conscious climate change behaviors. Maviş Demircioğlu (2019) aimed to determine the impact of a climate change program implemented with 5-year-old children in early childhood on their views of the concept of climate change. The experimental group was observed to give correct answers after the program when defining climate, explaining that climate is changing and addressing the situations that could affect them. They stated that climate change could harm living things, cause drought and cause sea levels to rise due to melting glaciers. Their solutions included using water and electricity economically, using A+ energy, generating cleaner energy through the construction of solar panels and wind turbines and using public transportation. After the program, the children in the experimental group developed ideas about climate change, while no improvement was observed in the control group (Duran, 2023).

With climate change education, it should be aimed for children to realize the importance of the balance of production and consumption in daily life, to have knowledge for a sustainable life, to learn by observing life cycles and to follow nature conservation efforts. Knowing and connecting with nature means loving nature and loving nature means caring for it. Therefore, processes that strengthen children's connection to nature should be prioritized in education (Anonymous, 2025).

Global climate change concern levels are related to the level of knowledge and awareness about this issue. From this perspective, it is necessary to increase the number of courses on global climate change and global warming in pre-university educational institutions and universities, and to give more space to content, programs, publications, documentaries, films, etc. related to this issue in the media (Semenderoğlu et al., 2024).

**Evaluation and Monitoring in Education**

At the end of the trainings, surveys should be conducted to understand how much the participants have internalized what they have learned. In climate change adaptation training, incorporating practical and on-site observations alongside theoretical knowledge will increase the effectiveness of these trainings.

**The Importance of Collaborations in Combating the Negative Impacts of Climate Change**

Climate change adaptation training is crucial for raising public awareness and developing effective strategies. For these trainings to be successful, raising participants' awareness based on local conditions and needs can make a significant difference. What's more collaboration between the public, private sector and civil society can develop joint solutions to address the negative impacts of climate change. International collaborative efforts on climate change adaptation can be encouraged.

**Approaches to Mitigating the Negative Impacts of Climate Change**

Renewable energy sources are presented as alternatives to fossil fuels. Energy sources such as solar energy, wind, hydroelectric, hydrogen, geothermal, biomass and current energy are renewable energy sources. Renewable energy sources are those that can mostly be obtained from nature without undergoing any production or transformation stages or processing, are not fossil-based, produce low $CO_2$ emissions when generating electricity, have less environmental damage than other energy sources, are constantly renewed and exist in nature ready for use (Seydioğulları, 2013; Gedik et al., 2024). Climate change not only affects living organisms and the sustainability of life, but also causes economic, social and political impacts, shaping international policies. Since reducing greenhouse gas emissions, which cause climate change, also affects countries' production activities, climate change is also a development issue. Therefore, countries must transform their policies in a way that enables them to develop without harming the environment (Dellal et al., 2015; Dellal et al., 2020).

The decreases in agricultural products increase the prices of processed food, causing the general price level to rise and thus inflationary pressure. The high share of food products in total consumer expenditures in developing countries causes consumer inflation in these countries to increase more rapidly compared to developed countries. This situation makes it difficult for the monetary authorities to control inflation in many countries (Başkaya et al., 2008; Başoğlu, 2014). In order to mitigate the impacts of climate change, changes need to be made in our energy and food production systems and renewable energy sources need to become widespread (Anonymous, 2025).

Turning off lights and unplugging electronic devices when not needed helps reduce energy consumption. By repairing, reusing, or repurposing clothing in different ways, individuals can develop habits that conserve natural resources. Choosing cloth bags instead of using plastic bags can reduce plastic use. Furthermore, individuals determining the amount of waste they produce and taking measures to reduce it is important for environmental protection. In addition, reducing carbon dioxide emissions and protecting nature's carbon cycle have become a necessity in the fight against climate change (Anonymous, 2025). The causes of the climate crisis are not limited to consumption habits and individual carbon emissions. Perhaps most importantly, it is necessary to examine historical production methods and energy source preferences (Ünsal, 2024). Countries should prepare their plans regarding energy resources by keeping economic priorities in the background and considering ecology and the environment (Gökkür and Şahin, 2015). In industry and transportation, the use of technologies that reduce carbon emissions should be disseminated. Incentives for the use of electric vehicles instead of all fossil fuel-powered vehicles should be increased.

When droughts or excessive rainfall occur frequently and intensely, crop losses increase. These changes in production volume affect costs (Dellal and McCarl 2007, Dellal 2018; Dellal et al., 2020). Drought-resistant crop varieties should be determined (Yalçın and Kara, 2014; Koç et al., 2016; Koç and Uzmay, 2016; Gökkür and Uysal, 2020; Hazar Kalonya, 2022).

Changes in temperature can affect the timing and duration of snowfall, thereby reducing the availability of water needed during the summer months. Groundwater availability is also negatively impacted by rising temperatures. Additionally, non-agricultural water demand in residential areas or certain industrial sectors can increase with rising temperatures. Consequently, intersectoral competition for water use can emerge (Dellal and McCarl, 2007; Dellal, 2018; Dellal et al., 2020).

Efficient irrigation systems such as drip irrigation should be widespread and water should be applied directly to the roots of the plants. Drought-resistant crops that require less water should be cultivated. Soil conservation practices should be implemented in agriculture to reduce water evaporation and conserve soil moisture. The reuse of water from other sources, such as rainwater, should be encouraged (Şalvarlı, 2023). Additionally, rainwater and vegetable washing water can be collected and used to irrigate plants (Anonymous, 2025). Water meters should be installed so that farmers can monitor their water usage and make adjustments for water conservation. Water-saving technologies such as water sensors should be used (Şalvarlı, 2023).

While comparing rainfall and temperature data on a monthly basis can be helpful in field studies to determine plant water requirements for that year, it may not always yield accurate results in climate change projections. Monthly and annual rainfall values should be evaluated both according to the water year and annually according to the January-December period and assessments should be made regarding the status of groundwater resources (Gökkür, personal communication, November 20, 2025).

Irrigation water requirements vary depending on the plant species and varieties. Where possible, the optimum amount of irrigation water should be given according to the needs of the variety (Gökkür, personal communication, November 20, 2025). Efforts to protect water resources by preventing over-irrigation, raising awareness among rural producers and implementing sanctions should be improved (Yalçın and Kara, 2014; Koç et al., 2016; Koç and Uzmay, 2016; Gökkür and Uysal, 2020; Hazar Kalonya, 2022).

Food production should be carried out by taking measures to protect water and soil resources. It is important to reduce the use of chemical fertilizers and pesticides, use water resources efficiently in agricultural production through optimal irrigation, reduce plant waste generated during production and use this waste as fertilizer.

Studies should be carried out to prevent excessive use of chemical fertilizers by growers (Yalçın and Kara, 2014; Koç et al., 2016; Koç and Uzmay, 2016; Gökkür and Uysal, 2020; Hazar Kalonya, 2022).

Depending on the nature of the wastewater, pre-treatment or advanced biological treatment facilities should be established or Urban Wastewater Treatment Facilities should be constructed. Moreover legislation should be prepared to prevent marine litter such as fishing nets, fishing lines, etc. and to collect existing litter. In order to reduce marine litter at its source, rehabilitation activities should be planned to reduce litter in rivers. Separate system applications for rainwater and urban wastewater should be implemented. National monitoring systems and programs should be developed in all seas for important habitats and special species that ensure the continuity of marine and coastal biodiversity. Besides, pesticide/packaging waste should be evaluated within the scope of hazardous waste management and legislation. The Environmental Impact Assessment process should be carried out in accordance with the ecosystem approach (Eyüboğlu et al., 2022).

Legal regulations regarding the increase of pasture areas and the improvement of existing areas should be updated every year to take production planning into account (Yalçın and Kara, 2014; Koç et al., 2016; Koç and Uzmay, 2016; Gökkür and Uysal, 2020; Hazar Kalonya, 2022).

Efforts to provide agricultural credit and insurance opportunities to rural producers in drought-affected regions should be increased (Yalçın and Kara, 2014; Koç et al., 2016; Koç and Uzmay, 2016; Gökkür and Uysal, 2020; Hazar Kalonya, 2022).

Climate change must be taken into account in the preparation of agricultural policies and the updating of relevant legislation (Yalçın and Kara, 2014; Koç et al., 2016; Koç and Uzmay, 2016; Gökkür and Uysal, 2020; Hazar Kalonya, 2022).

Legal regulations should be updated and prepared every year to encourage the use of renewable energy sources in the agricultural sector (Yalçın and Kara, 2014; Koç et al., 2016; Koç and Uzmay, 2016; Gökkür and Uysal, 2020; Hazar Kalonya, 2022). Indeed, although renewable energies have a great potential to reduce the destructive effects of fossil fuels on the environment, the possibility of such energy conversion processes having negative effects on ecosystems should not be ignored. Therefore, it is very important to act in accordance with ecological principles in the design and implementation of renewable energy projects. While large-scale adoption of renewable energy offers the potential to reduce greenhouse gas emissions and increase resource efficiency, it may run the risk of conflicting with biodiversity conservation and the sustainability of ecosystem services. However, spatial planning can help identify areas where such infrastructure will cause as little harm to biodiversity as possible. Ecosystems are undergoing rapid transformation in response not only to temperature changes, but also to climate change and other drivers of global change, such as changes in precipitation regimes, increases in atmospheric carbon dioxide levels, disruptions in the water cycle, differences in ocean chemistry and increases in the frequency and intensity of extreme weather events. The complex dynamics between environmental degradation and other stressors diversify the sensitivity of ecosystems to climate change and their responses to these changes. In this respect, it is critical that the development and implementation of renewable energy policies are not limited to technical solutions that only aim at emission reductions, but include holistic approaches that also center on the protection of ecosystems (Şimşek and Kurtuluş, 2025). Consequently, investments in renewable energy sources such as solar, wind, hydroelectricity and biomass energy, which utilizes waste, should be increased instead of fossil fuels. Activities should be undertaken to expand the use of public transportation.

It should be ensured that female and male producers in rural areas receive the same wages (Yalçın and Kara, 2014; Koç et al., 2016; Koç and Uzmay, 2016; Gökkür and Uysal, 2020; Hazar Kalonya, 2022).

Closely monitoring current developments related to climate change is of great importance, both for updating scientific research and for developing effective strategies to address it (Anonymous, 2025).

According to McKeown and Hopkins (2010), climate change education programs should focus on lifelong learning and include not only elementary and middle school students but also individuals of all ages (Barak, 2018).

## Conclusion

Significant increases in temperatures, decreases in rainfall and groundwater resources, reduced yields of some agricultural products, increased forest fires, severe and unexpected rainfall, tornadoes, biodiversity loss, deaths in some parts of the world due to heat waves, increased energy demand and consumption due to the increased need for cooling systems, some diseases transmitted from animals to humans, increased water demand for agriculture and domestic use, rising sea levels threatening groundwater resources in coastal areas with saltwater intrusion, decreased soil moisture due to increased evaporation, decreased snowfall, economic hardship for people working in sectors such as agriculture, livestock farming and fisheries due to unusuall changes in farming practices caused by changing climate parameters are among the negative impacts of climate change in recent years. Declines in agricultural yields due to climate change can lead to excessive price increases in some agricultural products. These yield losses negatively affect the supply processes of industrial facilities that use these products as raw materials, causing raw material shortages. Furthermore, as climate change makes it increasingly difficult to cultivate some agricultural crops, the cultivation of alternative crops in their place will become necessary in the future. Besides, the yield losses caused by climate change in agricultural production, resulting in price increases for some staple products, increase the risk of malnutrition in certain segments of society, negatively impacting public health and food security. To ensure that products with a high export share can be offered to consumers at affordable prices in the domestic market of the countries where they are produced, the necessary regulations must be implemented. Furthermore, in order to mitigate the effects of climate change on agricultural production and ensure supply security, it is crucial to conduct scientific and policy studies aimed at identifying and evaluating substitute products. Besides, reducing food waste and fighting obesity can have a significant impact on mitigating the negative effects of climate change.

To ensure sustainability in agriculture by adapting to climate change, it is necessary to develop crop varieties with low chilling requirements, high tolerance to extreme heat and cold and resistance to diseases and pests that may emerge following excessive rainfall. In addition, to monitor the effects of climate change on agricultural production and to develop effective strategies for disease and pest control, phenological monitoring needs to be implemented. Disease and pest control programs based on phenological monitoring should be updated annually.

By adding new rings to the value chains of all products or objects produced, such as reduction, reuse (including for different purposes) and recycling, we can contribute to the sustainability of the circular economy. In addition, when we reduce the amount of consumption of all products produced, use them for different purposes or recycle them, the circular economy can slow down the rate of extinction of the world's biodiversity.

Reducing tillage in agriculture will help slow the rate of increase in atmospheric $CO_2$ and protect soil structure and biodiversity. Besides to mitigate the negative effects of air pollution on human health, it is crucial to increase afforestation efforts, promote energy-efficient systems and effective filtration technologies in cities and industrial facilities, encourage green roof applications and implement pollinator-focused practices that strengthen urban-nature interaction and increase biodiversity.

The most effective way to solve the increasing energy demand is energy saving. Temperature changes and population growth in some parts of the world can cause differences in energy supply. By spreading the use of energy saving devices around the world, the world's total energy consumption can be kept at certain levels. In addition, renewable energy facilities should be located in areas where biodiversity will not be harmed.

In order to assess the impacts of climate change in a more comprehensive and accurate manner, it is necessary to develop scientific projections that take into account humidity, evaporation and temperature variables. Plant water consumption should be determined not only by the amount of evaporation, but also by the age of the plant, its growth vigor and soil structure. Moreover, to ensure the sustainability of groundwater resources, effective measures should be taken to prevent the drilling of unauthorized groundwater wells and the widespread adoption of technologies and practices that enhance water conservation in all sectors, especially agriculture, should be encouraged. In order to protect our water and soil resources, the use of pressurized irrigation systems should be expanded in agricultural lands suitable for irrigation.

Projects are being prepared and studies are being carried out all over the world to combat the effects of climate change. On the days when these projects will be announced around the world, 100 trees should be planted symbolically for each project (planting trees sequester carbon dioxide, increases biodiversity and help protect soil and water resources). In the meetings of awareness-raising and adaptation projects related to climate change, practices or activities regarding combating climate change should be included.

To prevent the negative impacts of climate change, mitigation and adaptation policies at national and international levels should be determined in line with the sustainable development goals. Preparing digital content, videos, brochures, books, meetings, workshops and seminars on the impacts of climate change and adaptation will help increase the positive impact of education. Developing a holistic approach to training that embraces all sectors and establishing standardization for climate change adaptation efforts will positively impact the sustainability of life worldwide. Furthermore developing sector-specific and disaster-specific training will also ensure success in combating climate change.

## Recommendations

Wetlands, agricultural lands and forested areas must be protected from practices that could disrupt the ecological balance, such as urbanization. Similarly, coastal areas hosting settlements, tourism regions, ports and transportation infrastructure need to have their resilience increased against rising sea levels and extreme weather events such as storms and tornadoes.

Increasing the number of green buildings that integrate biodiversity into urban life in both urban and rural areas, implementing ecological restoration efforts in all areas with ecological remnants and expanding green spaces in cities are fundamental elements of sustainable urban planning. Furthermore, preventing the establishment of industrial facilities in areas close to agricultural lands will provide long-term environmental benefits.

Improving awareness of the importance of conserving and enhancing biodiversity through increased educational activities, developing and implementing sustainable policies for the protection of agricultural lands and expanding afforestation activities to increase carbon sequestration as part of the fight against climate change are of great importance. Furthermore, to effectively combat natural disasters, it is necessary to prepare agreements that will strengthen international cooperation among countries.

Slowing the rate of depletion of water resources through water resource management necessitates meeting the water needs of different sectors in a balanced and sustainable manner. In this context, the need for drinking and domestic water, the ecosystem water requirements necessary for the continuation of biodiversity, the need for agricultural irrigation water and the water demands of the industrial, energy and tourism sectors should be addressed with a holistic approach. Promoting water conservation, effectively controlling groundwater wells and renewing irrigation networks that cause excessive water consumption or have reached the end of their economic lifespan are of great importance. Furthermore, transitioning to modern irrigation systems that allow for less water consumption will increase water efficiency.

To mitigate negative impacts such as increased flooding and soil erosion, infrastructure (drainage) projects for rainwater harvesting and utilization need to be widespread in all regions of the country. The development of technologies for the treatment and reuse of rainwater should be supported. In addition, ensuring the efficient use of wastewater in urban landscape areas and other sectors and making rainwater storage facilities mandatory in the construction of new landscape areas, are critically important for sustainable water management. Activities aimed at conserving water resources need to be diversified and expanded in scope. In this context, it is crucial that education and dissemination efforts are carried out in a planned and continuous manner to encourage the adoption of water-saving methods across all sectors.

To enable farmers to continue their activities in the agricultural sector and overcome the economic problems they face, reducing the negative impacts of climate change on agricultural production is of great importance. Implementing policies and practices aimed at the more optimal use of agricultural inputs that increase production costs is necessary to protect farmers' income levels.

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**Research Article**

# Development of learning achievement in career education using demonstration-based instructional packages for upper secondary students

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**Abstract**

This study investigated the effectiveness of demonstration-based instructional packages in enhancing learning achievement in Career Education among upper secondary students. A quasi-experimental design using a one-group pretest–posttest model was employed. The participants consisted of 38 Grade 12 students enrolled in a Career Education course at a public secondary school in Surin Province, Thailand. The intervention was implemented over 15 weeks, with one instructional hour per week, utilizing four instructional packages covering agricultural technology, animal husbandry principles, basic agro-industry, and career experience. Research instruments included lesson plans, demonstration-based instructional packages, a 40-item multiple-choice learning achievement test, and a student satisfaction questionnaire. Instrument quality was validated by subject-matter experts using the Item–Objective Congruence (IOC) index. Data were analyzed using descriptive statistics, instructional efficiency analysis (E1/E2), paired-samples t-tests, Effectiveness Index (EI), and satisfaction analysis. The results indicated that the instructional packages achieved an efficiency level of 81.05/80.20, exceeding the established 80/80 criterion. Students' posttest achievement scores ($\bar{x}$ = 32.08, SD = 2.53) were significantly higher than pretest scores ($\bar{x}$ = 17.21, SD = 2.57), $t(37) = 22.10$, $p < .001$. The Effectiveness Index value of 0.6524 reflected substantial learning improvement. Moreover, students reported a high level of satisfaction with the instructional approach ($\bar{x}$ = 4.32, SD = 0.77). These findings suggest that demonstration-based instructional packages effectively enhance learning achievement, instructional quality, and learner engagement in Career Education. The study provides empirical evidence to support the integration of structured demonstration-based pedagogy in vocational and competency-based education contexts.

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## Introduction

Contemporary education emphasizes holistic learner development, lifelong learning, and the acquisition of transferable competencies necessary for social participation and employability. In Thailand, the National Education Act B.E. 2542 (1999) and the Basic Education Core Curriculum B.E. 2551 (2008) institutionalize learner-centered pedagogy, competency-based learning, and decentralization of educational management to promote academic quality and workforce readiness (Ministry of Education, 2008; Office of the National Education Commission [ONEC], 1999). These policy directions align with international frameworks advocating active learning, experiential engagement, and authentic skill development as foundations of effective secondary and vocational education (Kolb, 2015; Prince, 2004).

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Within the secondary curriculum, Career Education integrates practical domains such as technology, food processing, basic engineering, entrepreneurship, and community-based skills, requiring instructional approaches that effectively link conceptual understanding with procedural competence (Ministry of Education, 2008). However, empirical evidence from many school contexts indicates that conventional teacher-centered instruction often limits student engagement, hands-on practice, and higher-order thinking, resulting in suboptimal learning outcomes (Prince, 2004). Local assessment data further reflect persistent achievement gaps in practical subjects, signaling the need for instructional innovation that systematically supports skill acquisition and learner motivation.

Instructional packages provide a structured framework that integrates learning objectives, content sequencing, learning activities, and formative–summative assessment into coherent learning units, enabling consistency, learner autonomy, and instructional fidelity (Boonkerd, 1999). Complementarily, demonstration-based instruction emphasizes modeling, observation, guided practice, feedback, and reflection, facilitating procedural learning and psychomotor skill development through social and experiential mechanisms (Bandura, 1986; Khammani, 2002; Kolb, 2015). Empirical studies consistently report that demonstration and hands-on approaches enhance learning achievement, engagement, and skill transfer, particularly in vocational and applied learning environments (Kolb, 2015; Prince, 2004).

Despite these theoretical and empirical advantages, limited research has systematically examined the integration of demonstration-based pedagogy with structured instructional packages in upper secondary Career Education contexts, particularly within Southeast Asian educational systems. This gap constrains evidence-based curriculum design and scalable instructional innovation. Therefore, this study investigates the effects of demonstration-based instructional packages on learning achievement among upper secondary students in Career Education. The findings are expected to contribute empirical evidence to instructional design research, support competency-based curriculum implementation, and inform pedagogical innovation in vocational and skills-oriented education.

**Objectives**

- Develop and evaluate the efficiency of demonstration-based instructional packages in Career Education based on the 80/80 efficiency criterion.
- Compare students' learning achievement before and after instruction using the demonstration-based instructional packages.
- Determine the effectiveness index of the demonstration-based instructional packages in Career Education.
- Examine students' satisfaction toward learning through the demonstration-based instructional packages.

## Method

**Scope of the Study**

This study examined the development of learning achievement in Career Education using demonstration-based instructional packages among upper secondary students. The scope of the study is defined as follows:

***Population and Sample***: The population comprised 237 Grade 12 students enrolled in Career Education courses at a public secondary school in Thailand during the first semester of the 2025 academic year. The sample consisted of 38 students from one intact class, selected through simple random sampling

***Time Frame:*** The intervention was implemented over a period of 15 weeks, with one instructional hour per week, yielding a total instructional time of 15 hours. A total of two additional weeks were allocated for administering the pretest and posttest and completing the data collection process.

***Content Scope:*** The instructional content covered four learning units: agricultural technology, animal husbandry principles, introductory agro-industry, and career experience. All instructional activities were delivered through demonstration-based instructional packages.

**Research Site**

The study was conducted at Thatum Prachasermwithaya School, located in Thatum Subdistrict, Thatum District, Surin Province, Thailand.

**Research hypotheses**

The research hypotheses were formulated as follows:

H1: The demonstration-based instructional packages in Career Education achieve instructional efficiency according to the 80/80 criterion.

H2: Students who learn through the demonstration-based instructional packages demonstrate significantly higher posttest learning achievement than pretest achievement.

H3: Students who learn through the demonstration-based instructional packages exhibit a high effectiveness index, indicating significant learning improvement.

H4: Students report a high level of satisfaction toward learning through the demonstration-based instructional packages.

**Research Design**

This study employed a quasi-experimental one-group pretest–posttest design to examine the effects of demonstration-based instructional packages on students' learning achievement in Career Education. The population consisted of 237 Grade 12 students enrolled in Career Education courses during the first semester of the 2025 academic year. A sample of 38 students from one intact class was selected using simple random sampling. The intervention was implemented over 15 weeks (15 instructional hours) and covered four instructional units: agricultural technology, animal husbandry principles, introductory agro-industry, and career experience.

The instructional intervention comprised four demonstration-based instructional packages supported by twelve lesson plans, each emphasizing modeling, guided practice, observation, feedback, and reflection. Prior to implementation, all instructional materials were reviewed and validated by three subject-matter experts for content relevance and instructional appropriateness using the Item–Objective Congruence (IOC) index, meeting the acceptance criterion of ≥ .50. Learning achievement was measured using a 40-item multiple-choice test, which demonstrated acceptable item difficulty, discrimination indices, and internal consistency reliability (KR-20). Students' learning satisfaction was assessed using a five-point Likert-scale questionnaire, validated for content validity and reliability using Cronbach's alpha.

Data collection followed a standardized procedure consisting of pretesting, instructional intervention, and posttesting. Instructional efficiency was evaluated using the E1/E2 efficiency criterion (80/80 standard), while learning achievement gains were analyzed using paired-samples t-tests. The effectiveness of the instructional packages was further examined using the Effectiveness Index (EI). Descriptive statistics were applied to analyze students' satisfaction levels. All statistical analyses were conducted to determine the instructional impact and learning improvement attributable to the demonstration-based instructional packages.

**Research Instruments**

Four research instruments were employed in this study: (1) lesson plans, (2) demonstration-based instructional packages, (3) a learning achievement test, and (4) a student satisfaction questionnaire.

**Lesson Plans:** Twelve lesson plans were developed to support the implementation of demonstration-based instructional packages across four instructional units: agricultural technology, animal husbandry principles, introductory agro-industry, and career experience. Each lesson plan specified learning objectives, instructional procedures, learning activities, instructional media, and assessment strategies aligned with the Basic Education Core Curriculum. The lesson plans emphasized modeling, guided practice, observation, feedback, and reflective discussion. Content validity and instructional appropriateness were evaluated by three subject-matter experts using a five-level rating scale. All lesson plans achieved acceptable mean ratings above the established criterion and were approved for classroom implementation.

**Demonstration-Based Instructional Packages:** Four instructional packages were developed to systematically organize instructional content, learning activities, and assessment procedures. Each package consisted of teacher guidelines, student instructions, learning standards, learning objectives, pretest and posttest tasks, content cards, activity cards, and performance-based practice tasks. The instructional packages were reviewed by three experts for content alignment, instructional coherence, and usability using the Item–Objective Congruence (IOC) index. All items achieved IOC values above the acceptable threshold of .50, indicating adequate content validity.

**Learning Achievement Test:** Students' learning achievement was measured using a 40-item multiple-choice test with four response options. The test covered all instructional units and was constructed based on a table of specifications aligned with learning objectives and content standards. Content validity was examined by three experts using IOC analysis, yielding IOC values ranging from .67 to 1.00. The test was piloted with a comparable student group to determine item difficulty, discrimination indices, and reliability. Internal consistency reliability was established using the Kuder–Richardson Formula 20 (KR-20), demonstrating acceptable reliability for research purposes.

4. Student Satisfaction Questionnaire: Students' satisfaction toward learning through the instructional packages was assessed using a 10-item questionnaire employing a five-point Likert scale. The instrument evaluated students' perceptions of instructional clarity, learning engagement, instructional media, activity design, and overall learning experience. Content validity was verified by three experts using IOC analysis with all items exceeding the .50 criterion. Reliability was determined using Cronbach's alpha coefficient, indicating acceptable internal consistency. Descriptive statistics were used to analyze students' satisfaction levels.

**Data Collection Procedure**

Data collection was conducted over a 15-week instructional period during the first semester of the 2025 academic year. Prior to the intervention, participating students completed a pretest using the learning achievement test to establish baseline performance. The pretest was administered under standardized classroom conditions and supervised by the researcher.

Following the pretest, students received instruction through demonstration-based instructional packages across four instructional units. Instructional activities emphasized modeling, guided practice, observation, feedback, and reflective discussion. Each instructional session was implemented according to the prepared lesson plans to ensure instructional consistency and fidelity.

Upon completion of the instructional intervention, students completed the posttest using the same learning achievement test, with reordered items and response options to minimize recall effects. Test administration procedures were identical to those used for the pretest.

In addition, students completed a student satisfaction questionnaire immediately after the posttest to evaluate their perceptions of the instructional approach, learning engagement, and instructional materials. Participation was voluntary, and responses were collected anonymously to ensure confidentiality and reduce response bias.

All collected data were coded and organized for statistical analysis. Learning achievement scores were used to examine instructional efficiency, effectiveness index, and pre–post learning gains, while questionnaire responses were analyzed to determine overall satisfaction levels.

**Duration of the Intervention**

This study was conducted during the first semester of the academic year 2025. The instructional intervention was implemented over a period of 15 weeks, with one instructional hour per week, yielding a total of 12 instructional sessions. In addition, two weeks were allocated for administering the pretest and posttest and completing the data collection process, as shown in Table 1.

**Table 1.** Schedule of instructional sessions and learning contents

| Session | Date (2025) | Instructional Package | Content |
|---|---|---|---|
| 1 | June 19 | Package 1 | Biotechnology |
| 2 | June 26 | Package 2 | Crop Production System Technology |
| 3 | July 3 | Package 3 | Livestock Housing System Technology |
| 4 | July 10 | Package 4 | Fundamental Principles of Animal Husbandry |
| 5 | July 17 | Package 5 | Types of Animal Farming |
| 6 | July 24 | Package 6 | Investment in Animal Farming |
| 7 | July 31 | Package 7 | Meaning and Importance of Agro-Industry |
| 8 | August 7 | Package 8 | Components of Agro-Industry |
| 9 | August 14 | Package 9 | Agro-Industrial Processing |
| 10 | August 21 | Package 10 | Product Preservation and Storage |
| 11 | August 28 | Package 11 | Essential Career Skills |
| 12 | September 4 | Package 12 | Income and Expense Accounting |

**Data Analysis**

Data were analyzed using both descriptive and inferential statistical methods in order to examine the quality of the instructional materials and the effects of the instructional intervention (Creswell & Creswell, 2018).

*Analysis of Instructional Package Quality as follows:*

First, the quality of the instructional packages was evaluated by subject-matter experts in terms of content appropriateness and suitability for students using the Item–Objective Congruence (IOC) index (Rovinelli & Hambleton, 1977).

Second, instructional efficiency was analyzed by calculating process efficiency (E1) and outcome efficiency (E2) in accordance with the 80/80 efficiency criterion (Brahmawong, 2010).

Third, students' learning achievement before and after the intervention was compared using a paired-samples t-test to determine statistically significant learning gains (Field, 2018).

***Analysis of Learning Achievement Test Quality:*** The quality of the learning achievement test was examined through psychometric analysis. Content validity was evaluated using IOC analysis (Rovinelli & Hambleton, 1977). Item quality was analyzed by calculating the difficulty index (p) and discrimination index (r) (Ebel & Frisbie, 1991). Internal consistency reliability was determined using the Kuder–Richardson Formula 20 (KR-20) (Kuder & Richardson, 1937).

***Analysis of Student Satisfaction Questionnaire:*** Students' satisfaction data were analyzed using item-level descriptive statistics, primarily frequency and percentage distributions, to determine overall satisfaction levels toward the instructional approach (Likert, 1932; Pallant, 2020).

## Results

This section presents the empirical findings of the study examining the effectiveness of demonstration-based instructional packages in enhancing students' learning achievement in Career Education. The results include analyses of instructional efficiency, pretest–posttest comparisons, effectiveness index evaluation, and students' satisfaction. The results are presented as follows.

As presented in Table 2, the mean pretest score was 17.21 (SD = 2.57), whereas the mean posttest score increased to 32.08 (SD = 2.53). The paired-samples t-test revealed a statistically significant difference between pretest and posttest scores, $t(37) = 22.10$, $p = .001$, indicating a substantial improvement in students' learning achievement following the implementation of the demonstration-based instructional packages.

These findings demonstrate that students achieved significantly higher learning outcomes after participating in the instructional intervention.

**Table 2.** Instructional efficiency of the demonstration-based instructional packages (n = 38)

| Measure | Maximum Score | ($\bar{x}$) | SD | (%) | E1/E2 |
|---|---|---|---|---|---|
| In-class Activity Performance (E1) | 60 | 48.63 | 3.04 | 81.05 | 81.05 / 80.20 |
| Posttest Achievement (E2) | 40 | 32.08 | 2.53 | 80.20 | |

Note. E1 = process efficiency; E2 = outcome efficiency.

The instructional efficiency of the demonstration-based instructional packages was evaluated using the E1/E2 efficiency criterion with a sample of 38 Grade 12 students. As shown in Table 1, students achieved a mean score of 48.63 out of 60 on in-class activity performance (E1), representing 81.05% (SD = 3.04). The mean posttest score (E2) was 32.08 out of 40, equivalent to 80.20% (SD = 2.53). The overall instructional efficiency was calculated as 81.05/80.20, which exceeded the established 80/80 criterion, indicating satisfactory instructional effectiveness.

**Unit-Level Learning Performance**

Students demonstrated consistently positive performance across all instructional units, with mean unit scores ranging from 3.71 to 4.63 (Table 3). The highest mean score was observed in Unit 1 ($\bar{x}$ = 4.63, SD = 0.71), followed by Unit 5 ($\bar{x}$ = 4.47, SD = 0.76), indicating strong engagement and mastery of foundational and applied content. The lowest mean score occurred in Unit 7 ($\bar{x}$ = 3.71, SD = 0.61); however, this value remained within a satisfactory performance range. Overall, the average unit performance score was 4.06, reflecting stable learning continuity and consistent engagement throughout the instructional intervention.

**Table 3.** Unit Performance Summary Across Instructional Packages (n = 38)

| Instructional Unit | Mean ($\bar{x}$) | SD |
|---|---|---|
| Unit 1 | 4.63 | 0.71 |
| Unit 2 | 4.08 | 0.71 |
| Unit 3 | 4.00 | 0.77 |
| Unit 4 | 3.79 | 0.78 |
| Unit 5 | 4.47 | 0.76 |
| Unit 6 | 4.05 | 0.46 |
| Unit 7 | 3.71 | 0.61 |
| Unit 8 | 4.08 | 0.97 |
| Unit 9 | 4.03 | 0.82 |
| Unit 10 | 3.97 | 0.72 |
| Unit 11 | 3.84 | 1.00 |
| Unit 12 | 3.97 | 0.43 |
| **Overall Mean** | **4.06** | — |

Note. Scores were based on a five-point rating scale reflecting students' performance in each instructional unit.

**Comparison of Pretest and Posttest Learning Achievement**

Students' learning achievement before and after the instructional intervention was compared using a paired-samples t-test with a sample of 38 Grade 12 students. As presented in Table 2, the mean pretest score was 17.21 (SD = 2.57), whereas the mean posttest score increased to 32.08 (SD = 2.53). The paired-samples t-test revealed a statistically significant difference between pretest and posttest scores, t(37) = 22.10, p = .001, indicating a substantial improvement in students' learning achievement following the implementation of the demonstration-based instructional packages.

These findings demonstrate that students achieved significantly higher learning outcomes after participating in the instructional intervention.

**Table 4.** Comparison of Pretest and Posttest Learning Achievement (n = 38)

| Measure | n | ($\bar{x}$) | SD | t | p |
|---|---|---|---|---|---|
| Pretest | 38 | 17.21 | 2.57 | 22.10 | .001 |
| Posttest | 38 | 32.08 | 2.53 | | |

**Note.** Paired-samples t-test; df = 37; significance level = .05.

**Effectiveness Index of the Instructional Packages**

The effectiveness of the demonstration-based instructional packages was evaluated using the Effectiveness Index (EI) with a sample of 38 Grade 12 students.

As shown in Table 3, the total pretest score was 654, while the total posttest score increased to 1,219 out of a maximum possible score of 1,520. The calculated EI value was 0.6524, indicating that students achieved approximately 65.24% of the possible improvement beyond their initial performance.

These results demonstrate a substantial learning gain attributable to the instructional intervention.

**Table 5.** Effectiveness Index (EI) of the Demonstration-Based Instructional Packages (n = 38)

| Test | Maximum Score | Total Score | Effectiveness Index (EI) |
|---|---|---|---|
| Pretest | 40 | 654 | 0.6524 |
| Posttest | 40 | 1,219 | |

Note. EI was calculated using the formula:EI = (Posttest total score – Pretest total score)/ (Maximum possible score – Pretest total score).

**Students' Satisfaction**

Students' satisfaction toward the demonstration-based instructional packages was analyzed using descriptive statistics, including mean scores, standard deviations, and percentage distributions. As shown in Table 5, the overall satisfaction level was high (M = 4.32, SD = 0.77, 86.34%). The three highest-rated items were: overall satisfaction with the course (Item 10; M = 4.53, SD = 0.62), fairness and coverage of assessment (Item 8; M = 4.47, SD = 0.68), and instructional preparation and time management (Item 1; M = 4.30, SD = 0.80). All individual items were rated at either high or very high levels, indicating positive student perceptions of instructional quality, learning engagement, assessment fairness, and practical applicability. These findings suggest that students perceived the instructional approach as effective, engaging, and supportive of their learning experience.

**Table 6.** Students' Satisfaction Toward the Demonstration-Based Instructional Packages (n = 38)

| Item | ($\bar{x}$) | SD | (%) | Satisfaction Level |
|---|---|---|---|---|
| 1. Instructional preparation and time management | 4.30 | 0.80 | 86.09 | High |
| 2. Teacher personality and communication | 4.00 | 0.93 | 80.00 | High |
| 3. Clarity of explanation and responsiveness | 4.26 | 0.71 | 85.26 | High |
| 4. Learning activities and classroom atmosphere | 4.32 | 0.70 | 86.36 | High |
| 5. Individual attention to students | 4.29 | 0.89 | 85.88 | High |
| 6. Use of learning resources and media | 4.33 | 0.78 | 86.67 | High |
| 7. Hands-on learning and critical thinking | 4.32 | 0.70 | 86.36 | High |
| 8. Fairness and coverage of assessment | 4.47 | 0.68 | 89.47 | Very High |
| 9. Applicability to daily life | 4.33 | 0.88 | 86.67 | High |
| 10. Overall satisfaction | 4.53 | 0.62 | 90.67 | Very High |
| **Overall** | **4.32** | **0.77** | **86.34** | **High** |

As summarized in Table 7, all four research hypotheses were supported. The instructional packages achieved efficiency exceeding the 80/80 criterion (H1), and students demonstrated significantly higher posttest achievement compared with pretest performance (H2). The effectiveness index indicated substantial learning improvement (H3), while student satisfaction was rated at a high level (H4). These results collectively confirm the effectiveness, instructional quality, and positive learner perceptions of the demonstration-based instructional packages.

**Table 7.** Summary of Hypothesis Testing Results

| Hypothesis | Statistical Indicator | Key Result | Decision |
|---|---|---|---|
| H1 | E1/E2 | 81.05 / 80.20 (>80/80) | Supported |
| H2 | Paired t-test | t(37) = 22.10, p = .001 | Supported |
| H3 | Effectiveness Index (EI) | EI = 0.6524 | Supported |
| H4 | Satisfaction (Mean %) | M = 4.32 (86.34%) | Supported |

Note. All hypotheses were tested at α = .05.

## Discussion

The findings of this study demonstrate that the demonstration-based instructional packages effectively enhanced students' learning achievement in Career Education across multiple dimensions, including instructional efficiency, academic performance, learning effectiveness, and learner satisfaction. The instructional efficiency values (E1/E2 = 81.05/80.20) exceeded the established 80/80 criterion, indicating that the instructional packages achieved high quality in both learning processes and learning outcomes. This result confirms that systematically designed instructional packages can promote consistency of instruction, structured sequencing of learning activities, and alignment between objectives, activities, and assessment, which collectively contribute to improved instructional effectiveness (Boonkerd, 1999; Wongsaphan, 2012). Similar findings have been widely reported in Thai educational research, where instructional innovations that meet the 80/80 benchmark are considered pedagogically sound and scalable within school contexts.

The significant improvement in posttest achievement compared with pretest performance further supports the effectiveness of the intervention. Students' posttest scores were significantly higher than their pretest scores, indicating substantial learning gains after exposure to the demonstration-based instructional packages. This outcome aligns with social cognitive theory, which emphasizes learning through observation, modeling, and guided practice, allowing learners to internalize procedural knowledge and skill execution more effectively (Bandura, 1986). Moreover, experiential learning theory suggests that concrete experience and active experimentation strengthen knowledge construction and skill transfer, particularly in vocational and applied learning contexts (Kolb, 2015). Consistent with international literature, active and hands-on instructional approaches generally yield higher learning outcomes than traditional lecture-based instruction, especially in subjects requiring procedural competence and practical application (Prince, 2004).

The Effectiveness Index (EI = 0.6524) further indicates that students achieved approximately 65% of the maximum possible learning improvement beyond their baseline performance. This metric provides meaningful evidence of learning growth beyond statistical significance, reflecting the magnitude of instructional impact. In Thai educational research, the Effectiveness Index is frequently used to quantify learning progression resulting from instructional innovation and has been interpreted as a robust indicator of instructional success when values exceed moderate thresholds. The relatively high EI obtained in this study suggests that demonstration-based instructional packages effectively facilitated incremental learning development across the instructional period.

Students also reported a high level of satisfaction toward the instructional approach (M = 4.32, SD = 0.77). The highest-rated aspects included overall satisfaction, fairness and coverage of assessment, and instructional preparation and time management. These perceptions reflect learners' positive engagement with structured instructional delivery, clarity of demonstrations, and transparency of evaluation procedures. Prior research indicates that student satisfaction is strongly associated with perceived instructional quality, relevance of learning activities, and opportunities for hands-on engagement (Noguera et al., 2024). The demonstration-based approach likely enhanced learner confidence, reduced ambiguity in task execution, and increased perceived usefulness of learning content for real-life application, thereby strengthening positive learning attitudes.

These findings are consistent with both Thai and international empirical studies demonstrating that demonstration-based and active learning approaches significantly improve student achievement, skill acquisition, and learning motivation in vocational and applied disciplines (Okotubu, 2024; Prince, 2004; Thissana Khammani, 2002). The integration of structured instructional packages further strengthened instructional fidelity and learning coherence, supporting sustainable instructional quality at the classroom level.

Nevertheless, the interpretation of results should consider methodological limitations. The study employed a one-group pretest–posttest quasi-experimental design, which may be susceptible to internal validity threats such as maturation, testing effects, and external influences (Luan & Saisy, 1995). Future research should incorporate control groups, randomized designs, or longitudinal follow-up assessments to enhance causal inference and examine the sustainability of learning gains. Additionally, reporting effect size indices and qualitative learning evidence may further strengthen the robustness of instructional evaluation.

From a pedagogical perspective, the findings support the adoption of demonstration-based instructional packages as a viable instructional strategy for Career Education and skill-oriented subjects. Such instructional models align well with competency-based education, experiential learning principles, and workforce-oriented curriculum frameworks. Scaling this approach may contribute to improving instructional quality, learner engagement, and practical skill development in secondary education settings.

## Recommendations

### Implications and Recommendations

The findings of this study provide several practical and academic implications for instructional improvement in Career Education and related vocational contexts.

- Teachers are encouraged to adopt demonstration-based instructional packages as a systematic approach to enhance students' procedural understanding, hands-on skills, and learning motivation, particularly in subjects that require practical competence and applied learning. Structured instructional packages can support instructional consistency, learning alignment, and formative assessment integration.
- School administrators should support professional development programs focusing on instructional design, demonstration pedagogy, and competency-based assessment to ensure sustainable implementation across subject areas. Institutional support, including instructional resources and collaborative curriculum development, can further enhance instructional quality and scalability.
- Curriculum developers and educational policymakers may utilize the empirical evidence from this study to support the integration of demonstration-based and experiential learning strategies into competency-based curriculum frameworks, particularly within vocational and career-oriented education systems.

### Future Research Directions

Regarding future research, subsequent studies should expand sample sizes across multiple schools and educational contexts to improve generalizability. More rigorous experimental designs, including randomized control trials or comparison group studies, are recommended to strengthen causal inference. Future research should also investigate broader learning outcomes, such as skill transfer, problem-solving ability, career readiness, and long-term retention. Additionally, exploring hybrid instructional models that integrate demonstration with digital technologies or game-based learning may provide further insights into scalable instructional innovation. Cost-effectiveness and implementation feasibility studies are also recommended to support policy-level adoption.

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