

Evaluation of a Contextual Problem-Based Learning (CoPBL) Model Integrated with Ethno-SSI Using a School Herbal Garden to Strengthen Students' 21st-Century Skills and Sustainable Living

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Abstract—This study develops and evaluates an integrated learning model combining Contextual Problem-Based Learning (CoPBL), ethnoscience and socio-scientific issues (Ethno-SSI), and a school herbal garden as an authentic learning resource. The herbal garden provides a contextual environment in which students connect scientific knowledge, local wisdom, environmental issues, health, and everyday practices through inquiry, experimentation, problem-solving, collaboration, and reflection. Participatory Action Research was used to develop and refine the model through collaboration with school administrators and teachers. The learning process was organized through the staged GARDEN Model, progressing from contextual engagement and exploration to research, experimentation, creation, presentation, and reflection. The findings showed consistent improvement in students' twenty-first-century skills, academic learning outcomes, and characteristics associated with self-sufficiency and sustainable living. The model demonstrates how contextual problem-based learning, local herbal knowledge, and authentic environmental resources can connect academic learning with practical experience, creativity, collaboration, problem-solving, and responsible resource use. The approach provides a practical framework for contextual, ethnoscience-oriented, and sustainability-focused education using locally available learning resources.

Keywords—contextual problem-based learning, COPBL, ethno-SSI, herbal garden, 21st-century skills, local wisdom, sustainable living.

I. INTRODUCTION

Contemporary education requires students to develop competencies that extend beyond the acquisition of disciplinary knowledge, including critical thinking, creativity, communication, collaboration, and the ability to apply knowledge in authentic contexts (Prahani et al., 2027). Critical thinking, problem solving, communication, collaboration, creativity, technological literacy, and the ability to apply knowledge in authentic situations have become essential learning outcomes. Learning should therefore provide opportunities for students to connect academic concepts with problems, resources, and experiences encountered in their everyday environments.

Constructivist and integrated-learning perspectives emphasize that meaningful learning occurs when students actively construct knowledge through experience and connect new information with existing understanding.

Contextual Problem-Based Learning (CoPBL) provides an appropriate framework for this purpose because learning begins with authentic problems situated within contexts that are meaningful to students. Rather than receiving knowledge as isolated information, students identify problems, formulate questions, investigate evidence, develop possible solutions, and communicate their findings. Problem-based and contextual learning can consequently strengthen the relationship between disciplinary knowledge and its practical application while encouraging students to become active participants in the learning process.

The contextual value of learning can be further strengthened by integrating ethnoscience and socio-scientific issues (Ethno-SSI). Ethnoscience connects formal scientific concepts with indigenous knowledge, cultural practices, and locally developed understanding of natural phenomena. Socio-scientific issues extend this connection by encouraging students to examine problems involving interactions among science, society, environment, health, culture, and decision-making. Integrating these perspectives allows locally available resources to become authentic contexts for scientific investigation and problem-solving rather than merely supplementary examples of academic content.

Local environmental resources are particularly valuable in this context because locally grounded and place-based learning can connect scientific concepts with authentic experiences, learner engagement, and contextual understanding (Macaumbao & Abdulmalik, 2026). Schools and surrounding communities contain biological, cultural, and social resources that can be transformed into learning environments. Previous educational approaches have emphasized the importance of connecting school learning with local and community resources to strengthen meaningful and competency-oriented education. However, the educational value of a local resource depends on how systematically it is incorporated into learning activities.

A school herbal garden provides a particularly rich contextual and ethnoscience-based learning resource. Herbal plants are closely connected with traditional knowledge, community culture, health practices, biodiversity, environmental management, household activities, and local economic practices. Consequently, the herbal garden can connect several disciplinary areas within the same authentic learning environment. Science can address plant classification, growth, ecosystems, medicinal characteristics, and environmental conditions; mathematics can address measurement, area, growth rates, and cost calculations; language learning can involve information searching, report writing, and presentation; technology can support documentation and information processing; and creative or vocational activities can involve product development, packaging, and utilization of herbal resources.

The use of school gardens and locally available learning resources has been associated with academic learning, scientific-process skills, analytical thinking, creativity, teamwork, environmental awareness, vocational development, and school-community cooperation (Wongsaphan, 2026). Nevertheless, school herbal gardens are not always used as systematic interdisciplinary learning environments. Their educational use may remain concentrated on isolated science activities, plant cultivation, or extracurricular programs. Such implementation limits opportunities for students to connect local knowledge with interdisciplinary inquiry, problem-solving, experimentation, creativity, and reflection.

CoPBL integrated with Ethno-SSI provides a conceptual mechanism for addressing this limitation because problem-based learning can promote active engagement, problem-solving, and critical thinking when students are required to investigate meaningful problems rather than passively receive information (Arifiani et al., 2025; Prahani et al., 2027). In this approach, local environmental and cultural resources can serve as the starting point for factual problems that require students to investigate evidence and connect scientific understanding with social and environmental considerations. Previous research on CoPBL integrated with Ethno-SSI has emphasized its potential to strengthen competencies related to creativity, communication, adaptability, problem-solving, critical thinking, and confidence. These competencies are closely related to the broader 21st-century skills required for meaningful participation in contemporary education and society.

The school herbal garden offers a suitable environment for operationalizing these principles. Students can begin with actual plants, cultivation conditions, medicinal uses, environmental problems, community knowledge, or resource-management issues. They can subsequently formulate questions, search for scientific and local information, conduct experiments, analyse observations, compare possible solutions, develop products or representations, communicate results, and reflect on their learning. In this way, the garden becomes a living laboratory connecting contextual problems, ethnoscience, interdisciplinary knowledge, and student-centered learning.

A structured pedagogical sequence is required to transform these opportunities into systematic learning. In the present study, the learning process is organized through the GARDEN Model, consisting of six interconnected stages: Grounding and Engagement, Asking and Exploring, Researching and Connecting, Doing and Experimenting, Enriching and Creating, and Narrating and Reflecting. The sequence moves students from initial interaction with authentic contexts toward questioning, investigation, interdisciplinary knowledge construction, experimentation, creative application, communication, and reflection. The GARDEN Model therefore provides an operational learning structure through which the principles of contextual problem-based and ethnoscience-oriented learning can be implemented using the school herbal garden.

This approach is also relevant to sustainable development. Herbal gardens provide opportunities for students to learn about biodiversity, responsible resource utilization, plant conservation, health, local knowledge, and community practices. Students can experience sustainability not only as an abstract concept but through decisions involving water use, plant maintenance, reuse of materials, shared resources, cultivation practices, and responsible utilization of natural resources. Sustainable learning therefore becomes embedded within everyday educational activities.

The approach is particularly relevant to the Sustainable Development Goals (SDGs). The integration of contextual, interdisciplinary, and locally grounded learning supports SDG 4 (Quality Education) by promoting meaningful and competency-oriented learning opportunities. The use of herbal plants and environmental resources can also provide educational connections with SDG 3 (Good Health and Well-Being) through knowledge of medicinal plants and healthy practices, SDG 12 (Responsible Consumption and Production) through responsible resource use, and SDG 15 (Life on Land) through awareness of plant resources, biodiversity, and environmental conservation. Thus, a school herbal garden can function simultaneously as an educational resource and as a practical context for developing sustainability-oriented knowledge, skills, and behaviors.

Despite these possibilities, an important research gap remains. Previous studies have examined contextual learning, problem-based learning, ethnoscience, local learning resources, school gardens, 21st-century skills, and sustainability from different perspectives. However, limited attention has been given to an integrated framework in which CoPBL and Ethno-SSI are operationalized through a school herbal garden using a structured interdisciplinary learning sequence. In particular, there is a need to determine whether such an approach can simultaneously strengthen 21st-century skills, academic learning outcomes, and characteristics associated with self-sufficiency and sustainable living.

Therefore, this study aims to develop and evaluate a Contextual Problem-Based Learning (CoPBL) model integrated with Ethno-SSI using a school herbal garden as an authentic learning resource. Specifically, the study aims to:

(1) develop an integrated learning process that connects contextual problems, local herbal knowledge, interdisciplinary inquiry, experimentation, creativity, and reflection; (2) evaluate changes in students' 21st-century skills after implementation; (3) evaluate changes in students' learning outcomes; and (4) examine the development of characteristics associated with self-sufficiency and sustainable living. The novelty of the study lies in transforming the school herbal garden into a structured CoPBL and Ethno-SSI learning environment through the GARDEN Model, thereby connecting local wisdom and authentic environmental resources with cognitive, collaborative, creative, and sustainability-oriented educational outcomes.

II. LITERATURE REVIEW

A. Contextual Problem-Based Learning

Contextual learning connects academic knowledge with situations that students encounter in everyday life. Rather than positioning learners as recipients of information, contextual learning encourages them to interpret authentic situations, identify relationships among concepts, and apply knowledge to meaningful problems. Problem-Based Learning (PBL) strengthens this process by organizing learning around problems that require investigation, discussion, decision-making, and solution development. These characteristics are consistent with constructivist learning, in which knowledge is actively developed through interaction and experience.

Contextual Problem-Based Learning (CoPBL) combines these principles by using real-life situations as the starting point for problem-oriented learning, consistent with studies showing that problem-based approaches can strengthen motivation, problem-solving processes, and critical-thinking development (Arifiani et al., 2025; Prahani et al., 2027). Students are expected to identify problems, formulate questions, search for relevant information, analyse evidence, develop possible solutions, and communicate their findings. This process can support critical thinking and problem-solving while simultaneously strengthening communication, collaboration, creativity, and independent learning.

The educational value of CoPBL is particularly relevant when the contextual problem originates from students' immediate environment. Local biological resources, environmental conditions, cultural practices, and community activities can provide authentic problems that connect theoretical knowledge with observable phenomena. Such contexts allow learning to extend beyond the classroom and provide opportunities for interdisciplinary investigation.

B. Ethnoscience and Socio-Scientific Issues

Ethnoscience emphasizes the relationship between formal scientific knowledge and knowledge developed within local communities and cultural traditions. Local knowledge concerning plants, food, health, agriculture, environmental management, and natural resources can provide meaningful contexts through which students examine scientific concepts. Rather than treating local

knowledge and scientific knowledge as unrelated domains, ethnoscience-oriented education provides opportunities to investigate their relationships through observation, inquiry, and evidence.

Socio-scientific issues (SSI) add a social and decision-making dimension to science learning. Issues involving health, environment, natural-resource utilization, sustainability, and community practices frequently cannot be understood through scientific knowledge alone. They require students to consider evidence alongside social, environmental, cultural, and practical consequences. The integration of ethnoscience and SSI therefore provides an appropriate foundation for learning based on local resources.

C. School Herbal Garden as an Authentic Learning Resource

A school herbal garden provides an authentic environment in which students can interact directly with biological resources and connect learning with local knowledge and everyday practices, similar to place-based inquiry approaches that use local environments to strengthen conceptual understanding and learner interest in science (Macaumbao & Abdulmalik, 2026). Herbal plants are relevant to scientific knowledge concerning plant characteristics, growth, ecosystems, biodiversity, and medicinal properties, while their cultivation and utilization are also associated with health, community traditions, resource management, and local economic activities.

The educational potential of a herbal garden extends across disciplinary boundaries. Science activities can involve plant identification, cultivation, growth conditions, and experimentation. Mathematics can be incorporated through measurement, area calculation, growth rates, quantities, and costs. Language learning can involve information retrieval, documentation, report writing, and oral presentation. Technology can support data collection and digital communication, while creative and vocational activities can include product development, design, processing, and presentation.

School gardens and local learning resources have been reported to support academic achievement, scientific-process skills, analytical thinking, creativity, teamwork, environmental awareness, and cooperation between schools and communities (Wongsaphan, 2026). However, the availability of a garden alone does not guarantee integrated learning. A systematic pedagogical process is required to transform the physical resource into an environment for inquiry, problem-solving, interdisciplinary learning, and reflection.

D. The GARDEN Model as an Operational Learning Framework

The school-herbal-garden learning process is organized through the GARDEN Model. The model consists of six sequential but interconnected stages: Grounding and Engagement, Asking and Exploring, Researching and Connecting, Doing and Experimenting, Enriching and Creating, and Narrating and Reflecting. These stages provide a structured pathway from authentic experience to inquiry,

knowledge construction, practical application, creative production, and reflection.

Table I presents the relationship between the six GARDEN stages and the principal learning activities supported by the school herbal garden. As shown in Table I, the GARDEN Model is compatible with contextual and problem-based learning because students begin with an authentic environment and progressively develop questions, evidence, solutions, and reflections. It is also compatible with ethnoscience-oriented learning because locally meaningful herbal knowledge can be investigated and connected with academic concepts.

TABLE I
LEARNING STAGES OF THE GARDEN MODEL.

Stage	Principal learning activities	Expected learning process
Grounding and Engagement	Direct interaction with the herbal garden and identification of local contexts	Interest, observation, contextual understanding
Asking and Exploring	Formulating questions and identifying problems	Inquiry, curiosity, problem identification
Researching and Connecting	Searching for information and connecting knowledge across disciplines	Information literacy, interdisciplinary understanding
Doing and Experimenting	Conducting practical activities, investigation, and experimentation	Application, problem solving, evidence generation
Enriching and Creating	Developing products, solutions, or representations	Creativity, collaboration, knowledge application
Narrating and Reflecting	Presenting findings and reflecting on learning	Communication, evaluation, reflective learning

E. Twenty-First-Century Skills and Sustainable Living

Twenty-first-century learning requires students to develop abilities that allow them to apply knowledge collaboratively and independently, and local-wisdom-integrated learning has also been used to strengthen 21st-century competencies within sustainability-oriented educational settings. Critical thinking and problem solving support evidence-based decisions; communication and collaboration support collective learning; creativity supports the generation of new ideas and products; and information and technology skills support access to and organization of knowledge. These competencies become particularly

meaningful when developed through authentic tasks rather than isolated exercises.

School-herbal-garden activities provide opportunities to develop these skills simultaneously. Students can formulate questions about plants, collect information, design investigations, distribute responsibilities, analyse findings, develop products, and communicate results. Such activities connect cognitive skills with practical action and social interaction.

The same learning environment can support sustainable-living characteristics. Herbal cultivation requires attention to water, soil, plant care, materials, biodiversity, and responsible use of resources. Learning activities can therefore connect educational outcomes with self-sufficiency, environmental responsibility, and informed decision-making. This relationship supports SDG 4 through quality and contextual education and can also provide learning connections with SDG 3, SDG 12, and SDG 15.

F. Research Gap and Conceptual Integration

Previous studies have examined PBL, contextual learning, ethnoscience, SSI, school gardens, local learning resources, 21st-century competencies, and sustainability. However, these elements are frequently examined separately or applied to specific disciplinary outcomes. A gap remains in the development of an interdisciplinary framework in which a school herbal garden serves as the authentic context for CoPBL and Ethno-SSI while a structured learning model guides students from contextual engagement through investigation, experimentation, creation, and reflection.

The present study addresses this gap by positioning the GARDEN Model as the operational learning sequence through which CoPBL and Ethno-SSI principles are implemented in the school herbal garden. The integration is expected to connect local herbal knowledge and environmental resources with academic learning, 21st-century competencies, and sustainable-living characteristics.

Figure 1 presents the conceptual integration of the school herbal garden, CoPBL, Ethno-SSI, and the GARDEN Model. The framework positions the school herbal garden as the authentic learning resource, CoPBL as the problem-oriented learning foundation, Ethno-SSI as the connection among scientific knowledge, local wisdom, and socio-environmental issues, and the GARDEN Model as the instructional sequence. The expected outcomes include 21st-century skills, academic learning outcomes, and sustainable-living characteristics.

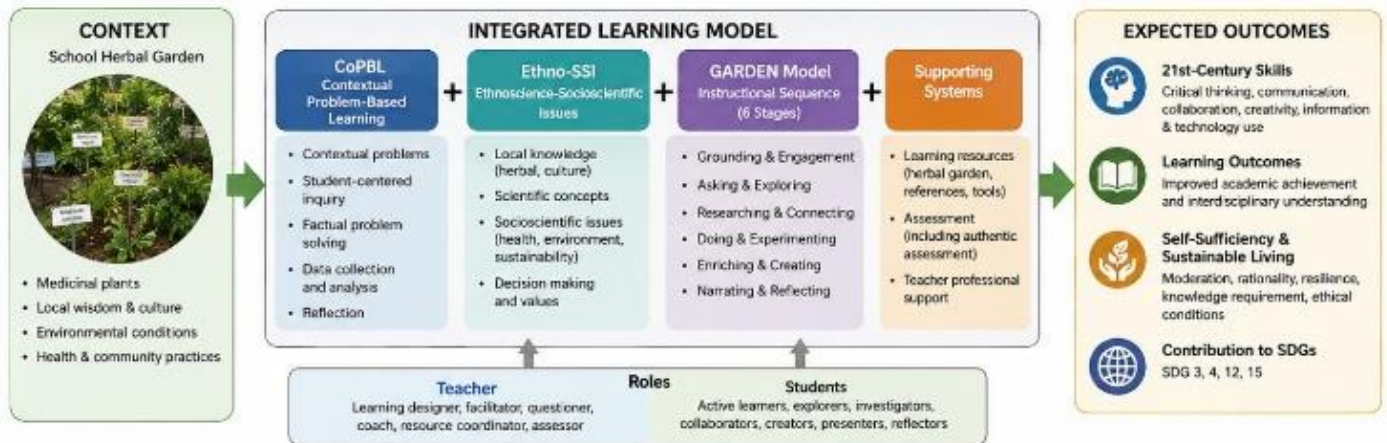


Fig. 1. Conceptual integration of CoPBL, Ethno-SSI, the school herbal garden, and the GARDEN Model.

The framework positions the school herbal garden as the authentic learning resource, CoPBL as the problem-oriented learning foundation, Ethno-SSI as the connection among scientific knowledge, local wisdom, and socio-environmental issues, and the GARDEN Model as the instructional sequence. The expected outcomes include 21st-century skills, academic learning outcomes, and sustainable living characteristics.

III. METHODOLOGY

A. Research Design

The study employed Participatory Action Research (PAR) to develop, implement, evaluate, and refine an integrated learning-management model using the school herbal garden as the principal learning resource. PAR was selected because development of the model required participation among researchers, school administrators, and teachers and allowed learning activities to be progressively improved through planning, implementation, observation, reflection, and refinement.

The research was conducted in two principal phases. The first phase focused on identifying existing conditions, needs, and possibilities for using school herbal gardens as integrated learning resources. The second phase involved development, implementation, evaluation, and refinement of the learning model through participatory action-research cycles.

B. Participants and Data Providers

The development process involved 45 data providers from four schools, comprising 4 school principals, 4 deputy principals, and 37 teachers. These participants contributed information concerning existing learning practices, school-herbal-garden resources, instructional requirements, implementation conditions, and model development.

The participating schools provided authentic educational settings in which herbal gardens could be connected with classroom and interdisciplinary learning activities. Administrators and teachers participated in the development and refinement process because implementation of an

integrated school-based model required coordination across subjects and school activities.

Student learning was evaluated through measures of 21st-century skills, academic learning outcomes, and characteristics associated with self-sufficiency and sustainable living. The available source manuscript does not clearly report the total number of students included in these student-level outcome assessments. Therefore, no student sample size has been estimated or introduced in the present revision.

C. Development of the Integrated Learning Model

The model-development process incorporated contextual learning, authentic problem solving, local herbal knowledge, interdisciplinary learning, practical activities, and reflection. The resulting GARDEN Model consisted of six stages described in Table I.

The integration with CoPBL and Ethno-SSI was conceptualized by treating the school herbal garden as the authentic context from which students could identify problems and connect scientific knowledge with local practices and socio-environmental considerations. The GARDEN sequence provided the operational structure for implementing these learning processes.

The model also incorporated four supporting elements: syntax, principle of reaction, social system, and support system. Syntax refers to the sequence of learning activities; the principle of reaction describes teacher responses and facilitation; the social system concerns interaction and collaboration among learners and teachers; and the support system includes learning resources, the herbal garden, instructional materials, technological resources, and other facilities required for implementation.

D. Participatory Action Research Procedure

The development and implementation process was conducted through three PAR cycles. Each cycle incorporated collaborative planning, implementation of learning activities, observation of the learning process, reflection on implementation, and refinement of subsequent activities.

During implementation, students interacted directly with the school herbal garden and progressed through the GARDEN stages. Activities included observation of authentic contexts, formulation of questions, information searching, interdisciplinary knowledge connection, practical investigation, experimentation, product or solution development, presentation, and reflection.

Figure 2 presents the participatory process used to develop and refine the integrated school-herbal-garden learning model. The iterative process enabled teachers and researchers to identify implementation difficulties and improve the organization of learning activities. The approach therefore treated model development as a collaborative school-based process rather than as the implementation of a fixed instructional package.

E. Data Collection

Data were collected using multiple methods consistent with the participatory design. Information concerning existing conditions and model implementation was obtained from administrators and teachers through participatory activities, observation, discussion, and reflection. Student outcomes were evaluated before and after implementation.

Three principal student outcomes were examined: 21st-century skills, academic learning outcomes, and characteristics associated with self-sufficiency and sustainable living. The 21st-century-skills assessment included dimensions related to critical thinking and problem solving, communication, collaboration, creativity and innovation, and information and technology use. Academic outcomes were assessed using the learning-outcome measure reported in the original study, while sustainable/self-sufficiency characteristics were evaluated using the corresponding rating instrument.

Qualitative observations were also used to document changes in students' learning behavior, including question formulation, division of responsibilities, selection of methods, interdisciplinary knowledge connection, resource use, collaborative activity, and reflection.

F. Data Analysis

Quantitative student outcomes were analysed descriptively by comparing measurements obtained before

and after implementation of the integrated school-herbal-garden learning model. Mean scores were used to describe changes in 21st-century skills and self-sufficiency/sustainable-living characteristics. Academic learning outcomes were evaluated using the reported mean scores and percentages before and after implementation.

The analysis focused on three principal comparisons: changes in overall and component-level 21st-century skills, changes in academic learning outcomes, and changes in self-sufficiency/sustainable-living characteristics. Qualitative observational evidence was used to support interpretation of the quantitative changes by identifying behavioral developments during implementation.

IV. RESULTS AND DISCUSSION

A. Development of the Integrated CoPBL–Ethno-SSI Learning Model Using a School Herbal Garden

The developed model positions the school herbal garden as an authentic learning environment in which students connect academic knowledge with local wisdom, environmental conditions, health-related knowledge, and everyday practices. The learning process is operationalized through the GARDEN Model, consisting of Grounding and Engagement, Asking and Exploring, Researching and Connecting, Doing and Experimenting, Enriching and Creating, and Narrating and Reflecting. Through these stages, students progress from direct observation and contextual engagement to questioning, investigation, experimentation, creative production, communication, and reflection.

The model also incorporates four interrelated components: instructional syntax, principle of reaction, social system, and support system. Teachers function as learning designers, facilitators, questioners, coaches, resource coordinators, and providers of formative feedback, whereas students actively explore, formulate questions, collect and analyse data, solve problems, collaborate, create products, and reflect on their learning. These characteristics are consistent with constructivist and integrated-learning principles emphasizing knowledge construction through authentic experience and meaningful connections across disciplinary boundaries.

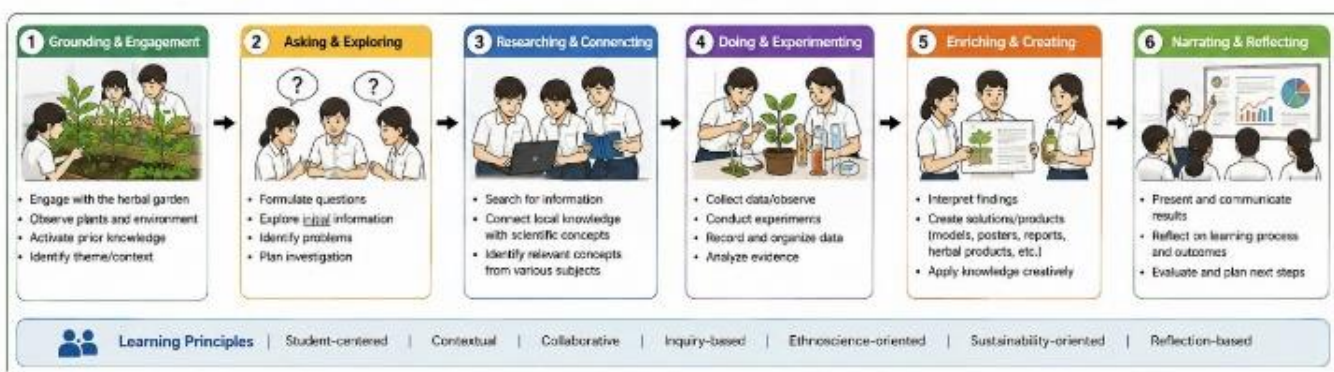


Fig. 2. Participatory Action Research process for development and refinement of the integrated learning model.

The school herbal garden provides a particularly suitable context for integrating CoPBL and Ethno-SSI because herbal plants are simultaneously associated with scientific knowledge, local culture, health practices, environmental management, and community life. Similar principles are evident in ethnoscience-based vocational learning, where local and cultural resources can be connected with scientific learning and higher-order thinking (Qori et al., 2020). The GARDEN Model extends this principle by providing a systematic instructional sequence specifically centered on the school herbal garden.

B. Improvement in Students' 21st-Century Skills

Students' 21st-century skills were assessed before and after implementation of the model. Table II presents the results for critical thinking and problem solving, communication, collaboration, creativity and innovation, and information and technology use. The overall mean increased from 3.22 to 4.25. All five dimensions improved, with the largest increase occurring in creative thinking and innovation (1.05), followed by communication and collaboration (1.04 each), critical thinking and problem solving (1.03), and information and technology use (0.96). These results are consistent with the original herbal-garden data.

TABLE II
COMPARISON OF STUDENTS' 21ST-CENTURY SKILLS BEFORE AND AFTER IMPLEMENTATION OF THE MODEL.

21st-Century Skills	Before (Mean)	SD	After (Mean)	SD	Difference
Critical thinking and problem solving	3.18	0.48	4.21	0.39	1.03
Communication	3.24	0.51	4.28	0.36	1.04
Collaboration	3.31	0.47	4.35	0.34	1.04
Creative thinking and innovation	3.12	0.52	4.17	0.41	1.05
Information and technology use	3.27	0.49	4.23	0.38	0.96
Total	3.22	0.39	4.25	0.31	1.03

The improvement can be explained by the nature of the learning activities, as project-based and design-oriented educational approaches can provide opportunities for students to develop creativity, scientific thinking, collaboration, and meaningful application of knowledge (Pratiwi et al., 2025). Students were required to observe actual herbal plants, formulate questions, investigate information, conduct experiments, analyse evidence, discuss possible explanations, and produce creative outputs. These processes move students beyond passive reception of knowledge and require them to use higher-order thinking in authentic situations. Such learning is consistent with contextual and constructivist perspectives in which meaningful knowledge develops through experience and active knowledge construction.

The development of communication and collaboration can also be related to the social organization of the GARDEN Model. Students worked in groups, distributed

responsibilities, exchanged information, discussed findings, and communicated their results. Previous studies using local learning resources have similarly emphasized the contribution of participatory learning to analytical thinking, creativity, teamwork, and the relationship between schools and communities (Wongsaphan, 2026).

The findings also show conceptual convergence with the CoPBL–Ethno-SSI framework. In the external study, employability skills were represented by creativity, communication, adaptability, problem-solving, critical thinking, and self-confidence (Qori et al., 2020). The external dataset should not be interpreted as part of the school-herbal-garden experiment because it involved a different population and research design. Nevertheless, both findings support the importance of authentic, contextual, and culturally relevant problems in developing transferable competencies.

C. Improvement in Students' Learning Outcomes

The effect of the learning model was also examined through students' academic learning outcomes. Table III presents the scores obtained before and after implementation. The mean score increased from 22.64 points (56.60%) before implementation to 33.72 points (84.30%) after implementation. The mean increase was 11.08 points, corresponding to a difference of 27.70 percentage points.

TABLE III
COMPARISON OF STUDENTS' LEARNING OUTCOMES BEFORE AND AFTER IMPLEMENTATION OF THE MODEL.

Evaluation	Full Score	Mean	SD	Percentage
Before implementation	40	22.64	4.18	56.60
After implementation	40	33.72	3.21	84.30
Difference	—	11.08	—	27.70

The improvement indicates that learning through the herbal garden was associated not only with skill development but also with greater understanding and application of academic knowledge, consistent with evidence that project-based and contextual learning can contribute to improved learning outcomes when students actively apply concepts in meaningful activities (Pratiwi et al., 2025). The authentic environment enabled students to relate concepts directly to observable situations. Mathematics could be applied to measurement and calculation, science to plant growth and environmental conditions, language to documentation and presentation, and technology to information retrieval and learning-material production.

This interdisciplinary connection is consistent with meaningful and integrated learning, in which knowledge becomes more useful when students recognize relationships among concepts and apply them to authentic situations. The herbal garden therefore functions not merely as an outdoor location but as a common context through which different disciplinary concepts can be connected.

CoPBL also provides a useful conceptual explanation for this pattern. Contextual problem-based learning emphasizes student involvement in discovering information and solving factual problems rather than simply receiving teacher explanations (Qori et al., 2020). In the present study, the GARDEN stages of Asking and Exploring, Researching and Connecting, and Doing and Experimenting provide comparable opportunities for active knowledge construction.

D. Development of Self-Sufficiency and Sustainable-Living Characteristics

The model was also evaluated in terms of students' self-sufficiency characteristics. Table IV compares the five measured characteristics before and after implementation. The overall mean increased from 3.23 to 4.31. Ethical conditions obtained the highest post-implementation mean (4.39), followed by moderation (4.34), knowledge requirement (4.31), rationality (4.27), and resilience (4.22). All dimensions therefore showed improvement following implementation of the model.

TABLE IV
COMPARISON OF SELF-SUFFICIENCY CHARACTERISTICS BEFORE AND AFTER IMPLEMENTATION OF THE MODEL.

Characteristics of Self-Sufficient Living	Before (Mean)	SD	After (Mean)	SD
Moderation	3.21	0.51	4.34	0.38
Rationality	3.18	0.47	4.27	0.40
Resilience	3.15	0.49	4.22	0.42
Knowledge requirement	3.27	0.46	4.31	0.36
Ethical conditions	3.34	0.43	4.39	0.34
Total	3.23	0.38	4.31	0.30

These changes can be understood from the direct relationship between herbal-garden activities and resource management. Students were required to care for plants, make decisions concerning the use of materials and water, plan activities, work cooperatively, and consider the consequences of their actions. The original observations showed behaviors such as using recycled materials, conserving water, caring for medicinal plants, and sharing equipment with other group members.

Such activities transform principles of sustainable and self-sufficient living into actual behaviors and are consistent with educational approaches that seek to strengthen environmental awareness and positive attitudes toward responsible interaction with the environment (Usmanovna et al., 2026). Rather than discussing moderation or responsible resource use only theoretically, students experience situations in which these principles guide everyday decisions. The finding is consistent with contextual education emphasizing the application of knowledge to individual, family, community, and sustainable-development contexts (Office of the Secretariat of the Education Council, 2018; Wongsaphan, 2026).

E. Changes in Students' Learning Behavior

Observational findings provide additional evidence concerning the learning process. At the beginning of implementation, students generally depended on teacher

guidance when identifying research topics and determining appropriate data-collection methods. As the activities progressed, students became increasingly independent in formulating questions, planning investigations, dividing group responsibilities, and selecting appropriate research methods.

Students also demonstrated greater ability to integrate knowledge across disciplines. They used mathematics for measurement and calculation, science to explain plant growth, language to record and communicate findings, and technology to search for information and develop learning materials. This pattern reflects the central principle of integrated learning, in which disciplinary knowledge is connected around meaningful problems rather than experienced as unrelated subject content.

The behavioral changes also correspond to the progression of the GARDEN Model. Asking and Exploring encourages curiosity and independent question formulation; Researching and Connecting develops information literacy and interdisciplinary thinking; Doing and Experimenting promotes evidence-based investigation; Enriching and Creating supports innovation; and Narrating and Reflecting develops communication and metacognitive evaluation.

These characteristics are also compatible with Ethno-SSI-based learning, which connects local resources and community knowledge with scientific reconstruction, evidence collection, problem analysis, and evaluation (Qori et al., 2020). Thus, the integration of CoPBL and Ethno-SSI provides a broader conceptual foundation for understanding why a school herbal garden can function effectively as an authentic learning resource.

F. Relationship with Employability Skills in CoPBL–Ethno-SSI Learning

The development of 21st-century skills observed in the herbal-garden study can be further interpreted using external evidence from the CoPBL–Ethno-SSI study. That study evaluated six employability-skill dimensions: creativity, communication, adaptability, problem solving, critical thinking, and self-confidence.

The external study reported an overall employability-skills improvement of 37.8% in school A and 29.6% in school B. At the indicator level, the highest N-gain was found for communication skills in school A (0.94) and problem-solving in school B (0.76), whereas critical thinking showed the lowest N-gain in both schools (0.38 and 0.11, respectively).

The comparison is useful because the employability dimensions overlap conceptually with several outcomes measured in the herbal-garden study. Creativity, communication, problem-solving, and critical thinking are also represented among the 21st-century skills in Table II. However, the numerical results should not be combined because the studies used different participants, instruments, educational levels, and research designs. The comparison instead demonstrates that contextual learning based on local environmental and cultural resources may support competencies that are relevant both to general 21st-century education and to future employability.

The CoPBL–Ethno-SSI study further emphasizes that contextual learning should allow students to solve factual problems while connecting scientific knowledge with traditions, culture, and local potential (Qori et al., 2020). This principle is directly applicable to herbal-garden learning because medicinal plants provide concrete links among scientific investigation, traditional knowledge, environmental management, health, and community practices.

G. Implications for the SDGs

The findings also have implications for the SDGs, particularly because sustainability-oriented learning can strengthen learner engagement, environmental awareness, quality education, and the application of interdisciplinary knowledge to authentic problems. Many reports regarding the SDGs have been published (Keisyafa et al., 2024; Adeoye, 2026; Glushchenko et al., 2027).

The improvement in students' academic outcomes and 21st-century competencies is directly relevant to SDG 4 (Quality Education) because the model promotes meaningful, interdisciplinary, participatory, and competency-oriented learning through locally available resources. The use of herbal plants can additionally create educational links with SDG 3 (Good Health and Well-Being) by connecting learning with medicinal plants and health-related local knowledge.

The observed practices of water conservation, reuse of materials, responsible plant management, and appreciation of natural resources provide connections with SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land). These sustainability principles are embedded within practical learning rather than presented only as theoretical concepts. This orientation is consistent with educational approaches that connect learning with real-life contexts, community resources, environmental responsibility, and sustainable development (Wongsaphan, 2026).

The integration of CoPBL, Ethno-SSI, and the GARDEN Model demonstrates how a locally available school resource can connect academic learning with local wisdom and global sustainability objectives. The school herbal garden functions simultaneously as a scientific learning environment, a context for problem-solving, a source of cultural knowledge, and a practical setting for developing responsible attitudes toward natural resources, while project-based integration of science, technology, and entrepreneurship can further strengthen the practical and value-creation dimensions of learning (Rahim & Mustafar, 2026).

CONCLUSION

This study demonstrates that integrating CoPBL and Ethno-SSI through the GARDEN Model can transform a school herbal garden into an authentic interdisciplinary learning environment. Students showed improvements in 21st-century skills, learning outcomes, and self-sufficiency characteristics after implementation. The model connects local herbal knowledge with inquiry, experimentation,

problem-solving, collaboration, creativity, reflection, and responsible resource use. The findings highlight the educational value of locally available resources for meaningful and sustainability-oriented learning. By linking academic knowledge, local wisdom, and environmental responsibility, the model provides a practical framework supporting quality education and broader SDGs, particularly SDG number 3, 4, 12, and 15.

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