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The Development of a Learning Unit to Promote Biodiversity Utilization in Agricultural Ecosystems

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Abstract

The objectives of this research were to 1) develop a learning unit to promote biodiversity use in agricultural ecosystems, 2) assess student learning outcomes related to their knowledge of biodiversity in agricultural ecosystems and to their skills of knowledge management, and 3) evaluate the impacts of learning to manage biodiversity in agricultural ecosystems on cultivators.

Agriculture is a major occupation in Thailand. Knowledge about utilizing biodiversity in an agricultural ecosystem is essential for safe food consumption. Teachers play a vital role in developing and managing learning opportunities for cultivators, leading to participatory learning. Important components of learning management are teachers, learning sources in the local community, learning units about managing agricultural ecosystem biodiversity, and collaborative learning assessments for developing the learning units. This study develops learning outcomes at secondary schools to address the use of biodiversity in agricultural ecosystems along with agricultural methods and teaching skills related to sustainable agricultural learning management. Teaching skills have been improved through the guideline Encouraging Learning Outcomes for Biodiversity in Agricultural Ecosystems, in accordance with the sustainable development goals of the United Nations.

Keywords: educational framework, agricultural, biodiversity, ecosystems

1. Introduction

Thailand is one of 193 nations that has made a commitment to achieving sustainable development goals by the 2030s. To do so, a committee for sustainable development was set up to support the goals. Additionally, Thailand signed in the international meeting “Rio +20,” which was established in 2012 to address food security relating to the use of agricultural biodiversity (Kimble, 2014). This is compatible with biodiversity conservation (Sadik & Sadik, 2014), which encourages the use of biodiversity to change cultivators’ methods for using resources because agriculture is a major occupation in Thailand. Therefore, knowledge of agriculture is important because it leads to sustainable agriculture, which supports sustainable development goals (SDGs; UNESCO, 2024). Moreover, environmental problems have continually increased due to population growth and industrial and technological development (Sadik & Sadik, 2014). An additional problem is biodiversity loss caused by agricultural expansion and pests. These critical issues impact economic and agricultural ecosystems. Thus, knowledge about utilizing biodiversity for sustainable agriculture is essential to help the next generation of farmers solve these problems (Burel et al., 2013; Lago et al., 2019; Li et al., 2019; Luangduangsitthideth et al., 2019; Pinkerton et al., 2018).

Biodiversity is a significant factor supporting sustainable agriculture (Bareille & Letort, 2018), necessitating a strategy for biodiversity conservation (Gough, 2017). In the case of Thailand, the topic of biodiversity has been established in the educational core curriculum and learning management of both formal and informal educational systems. Biodiversity lessons comprise three main topics: environmental education, communication, and participation (Jiméneza et al., 2015). These topics are included in lessons, integrated learning activities, and active learning (Jiméneza et al., 2015; Selby & Kagawa, 2018). Moreover, the process of activity-based learning encourages positive results and attitudes (Meekaew, 2018). For instance, outdoor activities provide experiences to students and improve knowledge management skills for teachers and cultivators (Wilson & Monroe, 2005). Teachers become more skillful at participatory teaching by applying role playing and fragmented learning (Yli-

Panula et al., 2018). Additionally, the teaching method needs to be suitable to the student's ability if it is to support learning, build awareness, and encourage positive attitudes toward biodiversity management (Gough, 2017; Hails, 2018; Malcom, 2001). The actions of teachers and the participation of cultivators lead to learning management. Furthermore, it is the teachers' responsibility to manage cultivators' knowledge and develop tools and guidelines to encourage the sustainability of biodiversity (Gough, 2017; Lago et al., 2019). Subsequently, students learn how to use biodiversity from local cultivators through activity-based learning (McGibbon & Belle, 2015). Additionally, learning management can be taught through agricultural geography, which helps to explain the differences among the agricultural products that cultivators grow (Crofts, 2014; Hayat et al., 2019). Schaal et al. (2012) proposed learning integration between schools and cultivators to develop knowledge about biodiversity in agricultural landscapes with a method of enquiry-based learning and by using technology as a tool to support learning management. This method creates teacher and student participation in the use of local biodiversity in agricultural landscapes. Also, it is an opportunity to deliver knowledge to the local youth (Nuraeni, 2018; Ontario EcoSchools, 2019). The agricultural ecosystem surrounding the schools is suitable for learning management, as can be seen from the ingredients of meals that the schools provide to students to educate them about vegetative ecosystems (Fischera et al., 2019).

Managing knowledge and changing the behavior of biodiversity utilization are pivotal for community participation (Singh & Rahman, 2012). Knowledge about forecasting the times and risk zones for pest infestation is essential for reducing future costs (Johnson, 2010). Therefore, the objectives of this research are to 1) develop a learning unit to promote biodiversity utilization in agricultural ecosystems, 2) assess learning outcomes related to biodiversity in agricultural ecosystems and to the skills of knowledge management of students, and 3) evaluate impacts of knowledge management related to biodiversity in agricultural ecosystems on cultivators. This study also supports sustainable development and food security in accordance with the sustainable development goals of the United Nations as stated in Goal 4 (Quality education), Goal 12 (Responsible consumption and production), and Goal 15 (Life on land; UNESCO, 2024).

2. Methods

2.1 Target Sample

Twenty-four students from grades 7 to 9 and one teacher from each school were selected to participate in this research. Additionally, teachers from the science and social studies departments, or those interested in participating, were invited. Three cultivators were included, representing different ecosystems: 1) the rice field ecosystem, 2) the vegetable ecosystem, and 3) the orchards ecosystem. Furthermore, three curriculum development experts were involved: an education specialist, a teacher with expertise in curriculum development, and a professor specializing in curriculum development.

2.2 Identify Subsections

Teachers play a role in developing a learning process by applying research along with knowledge gained during the field study with the cultivators. This process helps to obtain learning outcomes that can change the behavior of teachers, students, and cultivators in utilizing biodiversity. The process consists of four steps, including studying general information about agriculture, developing learning units about utilizing biodiversity in agricultural landscapes, testing the learning units, and assessing and improving the learning units with cultivators to create "the best practice" for utilizing biodiversity in agricultural ecosystems in a sustainable way, as presented in Figure 1.

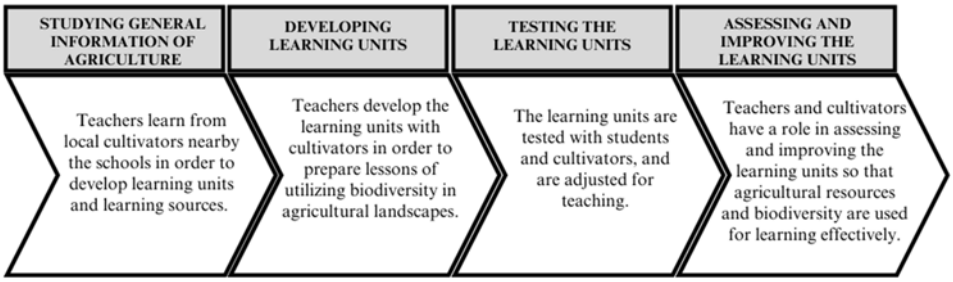

Figure 1. The Process of Knowledge Management to Encourage *Learning Outcomes for Biodiversity in Agricultural Ecosystems*

2.3 Sampling Procedures and Research Design

Encouraging Learning Outcomes for Biodiversity in Agricultural Ecosystems is an example of action research. Prior to conducting the fieldwork and interviews, all key questions had been approved by Mahidol University Center for Ethical Reinforcement for Human Research and Institutional Review Boards **(**MU-IRB**)**. The research process was divided into three steps as follows:

Step 1: The data of biodiversity utilization in the agricultural ecosystem were collected. Such ecosystems included rice fields and vegetable and perennial ecosystems. Ten cultivators for each ecosystem were selected with a chain sampling method. This method was suggested by the agricultural extension officer and carried on to the next cultivators. Subsequently, a focus group discussion and in-depth interviews with the cultivators were conducted. Key topics included characteristics of the ecosystem, living organism components of the ecosystem at different production seasons, methods of management (from soil preparation to management after harvesting and to using ecological products), and specifying learning methods and recording data. Then, the data from the interviews and focus group discussion were analyzed by content analysis.

Step 2: Participatory action research was conducted to develop the curriculum of "Encouraging Learning Outcomes for Biodiversity in Agricultural Ecosystems" with the collaboration of science and social studies teachers and three experts in curriculum development. After the curriculum was examined by the experts, it was adjusted prior to use with students from grades seven to nine.

Step 3: In-depth interviews were conducted with cultivators who possessed sources of agricultural information related to places the students had visited. The key questions included biodiversity management to assess the behavioral changes in the use of biodiversity after attending the learning unit. The research process was carried out as presented in Figure 2.

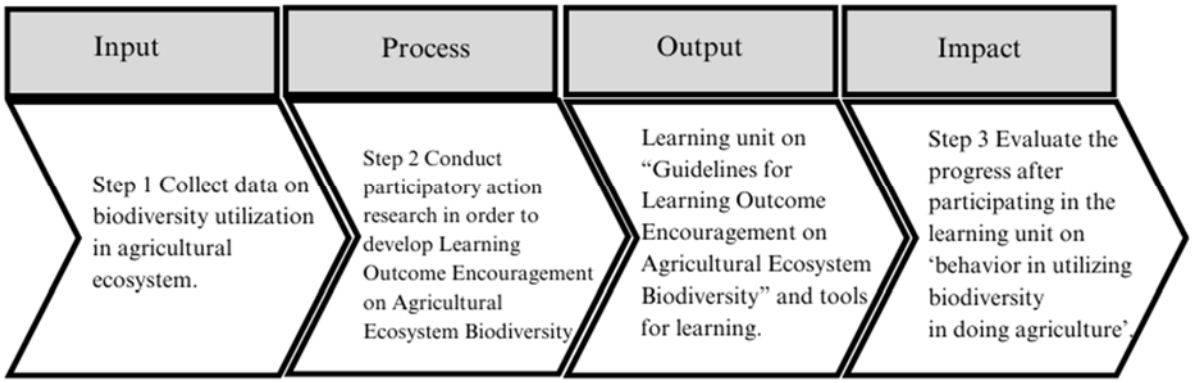

Figure 2. Research methodology

2.4 Research Tools

1) Key questions were designed for group discussion to evaluate the learning method and biodiversity management of cultivators and to select learning sources.

2) Tools for recording biodiversity data were created for students, including a questionnaire, observation form, seasonal calendar, biodiversity map, cross section photograph, and important agricultural activities.

2.5 Data Analysis

1) Qualitative data from the group discussion, interviews, and learning unit assessments were analyzed by content analysis and descriptive analysis.

2) Quantitative data was analyzed by descriptive analysis consisting of means and standard deviations.

The students' work was evaluated and compared by one simple t-test analysis.

3. Results

3.1 An Educational Framework Promoting Biodiversity in Agricultural Ecosystems

The learning unit for management of biodiversity focused on students learning from their communities. The students had opportunities to interact with community members, recall their knowledge of what they had learned,

practice self-study, improve language and communication skills, and play roles in knowledge management and communication for problem-solving in their local communities. To implement the learning unit, five subunits were designed that took approximately 12 hours to complete. Additional learning hours were added so that students could learn more from cultivators. Further detail about the learning unit is presented in Table 1 and Figure 3.

Table 1. Learning Unit

Content	Learning activities
Subunit 1: Study biodiversity utilization of cultivators in a study area (2 hours)	
1) General information of a study area related to the practice of agriculture 2) Information from cultivators in the study area about biodiversity and three types of agriculture; rice fields, orchards, and vegetable plantations. 3) Problems with and comparisons between monoculture and integrated agriculture. 4) Significant information for cultivators on selecting species for cultivation and on species that should be cultivated 5) Biodiversity use in the study area, including data of the cultivators for decision-making in cultivation 6) Assumption: improvement in data recording would help cultivators sell more biodiversity products.	1) Provide general information of the study area about suitability in land use for agriculture. 2) Conduct a student group discussion on suitability of the study area for agriculture. 3) Plan a map activity about biodiversity and the location of a student's house. 4) Describe problems and comparisons between monoculture and integrated agriculture. 5) Provide biodiversity information about the study area to students. 6) Conduct a student group discussion on the topic "An improvement in data recording would help cultivators gain more biodiversity products." 7) Divide students into three groups and assign one question to each group. 8) Select questions to set goals for the study in accordance with students' assumptions.
Subunit 2: Planning for data collection (2 hours)	
1) Sample selection from two villages adjacent to schools 2) Scope of the study 3) Specified study method 4) Questionnaire for cultivators design	1) Revise learning unit one and the selected questions by each student group. 2) Describe general information about the administrative region, agriculture, and cultivators in the study area. 3) Conduct a student group discussion to specify the scope of the study. 4) Describe the tools and methods of biodiversity data collection to the students. 5) Conduct a student group discussion to select and specify tools and methods for interviews according to the target goal of each group.
Subunit 3: Data collection (2 hours)	
1) Classroom questionnaire test 2) Cultivator data collection	1) Divide students into groups to test a questionnaire in a classroom. Then, adjust and correct as appropriate. 2) Divide students into groups to collect data from the cultivators.
Subunit 4: Study conclusion (2 hours)	
1) Existing information from the cultivators on selecting cultivated and uncultivated species including details of each species 2) Methods that cultivators use to record information (how many methods and frequency of each method) 3) The crop calendar of each cultivator 4) Discussion of assumptions 5) Recommendations for the improvement of the cultivators' recordkeeping	1) Collect data from the cultivators by using selected tools. 2) Divide students into groups to review the information received from the cultivators and determine whether it is different or similar to students' assumptions and recommendations for cultivators' improved recordingkeeping. 3) Invite the cultivators who were interviewed to participate in a meeting to receive data back from the students.
Subunit 5: Presentation of the returning data and evaluation of the students' learning and recommendations (4 hours)	
1) Appointments with cultivators, including a meeting location 2) Media and presentations 3) Evaluation forms for students' learning and recommendations 4) A meeting and an evaluation 5) Summary of the meeting results	1) Divide the students into groups to analyze information from the cultivators and create media for presentation. 2) Conduct a meeting to evaluate students' learning and recommendations. 3) Divide students into groups to summarize the meeting results.

Figure **3**. The Educational Framework for Promoting Biodiversity in Agricultural Ecosystems

3.2 Evaluation Results

The evaluation results of the learning unit on the utilization of biodiversity by cultivators in Phutthamonthon District by specialists received a mean score of **4.02**, which is a good level. The specialists made the following recommendations.

Table 2. Evaluation Results of the Learning Unit

No.	Lists of Evaluation	M(SD)	Level of suitability
1	Learning unit is complete and suitable, and the details relate to each other.	4.20(.44)	Good
2	Learning management plan relates to specified learning units.	4.00(0)	Good
3	Learning management plan comprises all important components, which relate to each other.	4.00(0)	Good
4	Writing about the plan's important content is accurate.	3.80(.83)	Good
5	The grade-level indicators, interval indicators, and learning outcomes cover the content and help learners develop Knowledge Practice Attitude.	3.80(.44)	Good
6	Learning objectives develop the knowledge, skills, processes, and attitudes of students.	4.40(.54)	Very good
7	The content is suitable to the time duration and grade-level indicators, interval indicators, and learning outcomes.	4.40(.54)	Very good
8	Learning activities from the first to last steps follow a process of learning management or separate into different steps as appropriate.	4.00(.70)	Good
9	Learning activities are suitable to the content and to the educational levels of the students.	4.00(0)	Good
10	Learning activities are diversified and practical and help develop the knowledge, processes, and attitudes of learners.	3.60(.54)	Good
11	Learning activities support the thinking process of students.	4.00(0)	Good
12	Learning activities insert ethics in accordance with desirable social attributes.	4.20(.44)	Good
13	Activities focus on students' learning from real practice.	4.40(.54)	Very good
14	The learning management plan specifies tools, equipment, media, and diversified learning sources that are suitable and compatible with the content and the learning activities.	3.80(.44)	Good
15	Students use media and learning sources by themselves.	4.40(.54)	Very good
16	The learning management plan assigns suitable tasks and duties.	4.00(0)	Good
17	Students design tasks based on their knowledge and creativity instead of following their teacher's instructions or working on assignment sheets.	4.20(.44)	Good
18	The measurements and assessments relate to standards, indicators, and learning outcomes appropriately.	3.40 (.89)	Moderate
19	Students participate in measurement and assessment.	3.60(.54)	Good
20	The learning unit has a management plan to develop learning effectively.	4.20(.44)	Good
Total		4.02(.41)	Good

3.3 Learning Outcomes from the Educational Framework to Promote Biodiversity in Agricultural Ecosystems with Teacher Participation in the Activities

Regarding assessment of the students' learning outcomes, the teachers who participated in the research observed the students' performance and examined their work at every step. Four criteria were used to evaluate the students' work, including styles of work, language in communication, content, and presentation time. Overall, the result of the evaluation was high and the assessment score of the learning outcomes was statistically significant at .00 **(**t = 43.01**)**. The details are presented in Table 3.

Table 3. Results of the evaluation of the suitability of the students' work

Criteria for evaluation	M(SD)	Level of suitability	t (Sig)
Styles of work	4.25 (.46)	High	43.01 (.00)*
Language in communication	4.12 (.35)	High	
Content	4.37 (.51)	High	
Presentation time	4.37 (.51)	High	
Average	4.25 (.45)	High	

Note. * Correlation is significant at $p < .05$.

3.4 Important Components of Knowledge Management of Agricultural Ecosystem Biodiversity Include Five Significant Components

1) Teachers who instruct science or social studies have a role in managing learning because the subjects taught relate to agricultural ecosystems and biodiversity.

2) Cultivators are local people residing in the community who own a learning source adjacent to a school. This allows students to access the site and learn with the cultivators after school hours.

3) The guidelines for Encouraging Learning Outcomes for Biodiversity in Agricultural Ecosystems are tools

designed to help teachers manage the learning process.

4) Assessment results from teachers, students, and cultivators assist in the examination and assessment of students' learning outcomes.

5) Adjustment of the learning guidelines is required to suit the situations and goals of the students and cultivators.

3.5 Effectiveness of the Encouraging Learning Outcomes for Biodiversity in Agricultural Ecosystems

Testing the results Encouraging Learning Outcomes for Biodiversity in Agricultural Ecosystems showed that new knowledge from teachers, students, and cultivators increased with a statistical significance of .05. Also, the cultivators' attitudes and awareness in utilizing biodiversity significantly increased. This is because when the cultivators planned their agricultural activities for the next year, they changed their agricultural methods as recommended in the learning units. This is compatible with Mumpuni et al. (2022), who conducted a study to design biodiversity learning through a research and development process, consisting of five steps: research and information-gathering, planning, initial product development, preliminary field testing, and product revision. The assessment and review of the module showed that students' understanding and awareness of the importance of local biodiversity increased. The success of the learning process depended on integrating farmers' expertise and community learning resources into the curriculum and practical applications (Gurung & Thapa, 2023; Rehman et al., 2023). Additionally, students' knowledge of biodiversity empowered them to become a mechanism for biodiversity conservation in agricultural areas (Id Babou et al., 2023; Solv et al., 2023). Teachers also played a crucial role in engaging farmers in the community to change agricultural practices toward sustainability and efficiency. The study found that such participation significantly impacted the adoption of biodiversity-based agricultural practices ($p < .05$; Goldman & Alkaher, 2024; Gurung & Thapa, 2023). The students who raised questions about agricultural ecosystem biodiversity, such as in rice fields, vegetable plantations, and orchards, contributed to the concept of a geographical ecosystem that is significant for biodiversity learning and the assessment of ecosystem utilization (Ince & Sahin, 2021).

3.6 Results From Using a process of Knowledge Management in Encouraging Learning Outcomes for Biodiversity in Agricultural Ecosystems With Cultivators After Participating in the Learning Units

The results from participating in the activities of the five learning units showed that the cultivators agreed that students should learn about agricultural biodiversity. The cultivators were pleased to participate in the activities and develop learning units with the teachers. Meanwhile, the teachers were interested in using the learning units to educate other students. Furthermore, the students who completed the learning units can become mentors for new student groups in the following year.

Based on the participatory learning management with cultivators, the cultivators volunteered to support the school's agricultural activities by purchasing agricultural products from the school. However, the products must meet the production standards that the cultivators had taught the students, which serves as motivation for the students to continue learning. Furthermore, the students who participated in the project were able to manage the knowledge they had previously gained and share it with the cultivators. This aligns with Sørensen et al. (2021), who stated that local farmers' knowledge is crucial in learning management because each locality is different. Teachers act as experts in linking the curriculum knowledge taught in schools with local knowledge. The study showed that the learning outcomes from collaborative efforts with schools led to behavioral changes in farmers and the community, as well as the integration of local knowledge and the dissemination of new knowledge derived from research, contributing to sustainable agricultural practices (Ataei et al., 2021; Silici, 2021). Additionally, activities that encouraged farmers and students to learn about local biodiversity positively impacted their knowledge and attitudes toward biodiversity-based agriculture (Christ, 2022).

The results from Encouraging Learning Outcomes for Biodiversity in Agricultural Ecosystems in collaboration with cultivators will support the United Nations' SDGs as stated in Goal 4 (Quality Education). This process enables farmers to learn alongside teachers, facilitating lifelong learning for the farmers and creating agricultural practices that support biodiversity. This will lead to safe agricultural production for both consumers and farmers, as well as a process of monitoring and evaluating safety through collaborative learning with teachers and students. This will contribute to the sustainability of agricultural resources, promote resource recycling in agricultural areas, and foster pride in sharing knowledge with students, aligning with Goal 12 (Responsible Consumption and Production) and Goal 15 (Life on Land; UNESCO, 2024).

3.7 Teachers' Roles in Supporting Sustainable Agricultural Ecosystems

Teachers play a crucial role in promoting awareness and behavior among students and facilitating knowledge exchange with farmers to design learning models based on the school curriculum and agricultural areas, aiming to

create sustainability within the agricultural ecosystem (Goldman & Alkaher, 2024). Additionally, teachers introduce new concepts about safe agricultural practices to pass on to students. Thus, Encouraging Learning Outcomes for Biodiversity in Agricultural Ecosystems (Slimi et al., 2021) fosters collaborative learning among farmers, teachers, and students, raising awareness of safe farming practices that students can apply in school lunch programs (Slick & Tewell, 2021). Moreover, teachers and cultivators evaluated the knowledge gained from the learning units as appropriate for students. Farmers who participated in these units stated, "Biodiversity utilization is necessary, and we will develop agricultural landscapes for students." This statement reflects the farmers' awareness of sustainable agricultural development. It aligns with Laurett et al. (2021), who indicated that farmers embrace the concept of sustainable development by supporting biodiversity or practicing crop rotation to generate income and impart knowledge to the next generation (Sonko et al., 2021).

Agricultural landscapes and schools serve as learning resources for students. Based on this study, some students are interested in pursuing agriculture within their communities. Therefore, the knowledge gained from farmers is a crucial factor supporting sustainable agriculture. As mentioned earlier, teachers are responsible for developing and creating the learning units. This is consistent with Hunter et al. (2020), who emphasized that teachers play a key role in managing learning in out-of-classroom settings, combining theoretical education with hands-on activities. They also set learning goals that differ from traditional classroom learning by incorporating project-based learning. This approach enables teachers to encourage student engagement, allowing students to choose their learning paths and gain real-life experiences based on their interests, which contributes to lifelong learning (Miller et al., 2021; Pedler et al., 2020). Therefore, learning in agricultural settings helps students understand agricultural processes that impact food safety and security within the community surrounding the school. It is essential to raise awareness among teachers, students, and farmers about biodiversity in agricultural areas. Hence, teachers should be trained to understand agricultural biodiversity to become future drivers of this initiative (Id Babou et al., 2023).

The role of teachers in promoting sustainability within agricultural ecosystems will support the United Nations' Sustainable Development Goals (SDGs) as stated in Goal 4 (Quality Education) by integrating knowledge from the school curriculum with local agricultural knowledge and using local resources to enhance the quality of education. This approach meets the community's needs for sustainable agricultural development, creating safe food production processes that reduce the use of agricultural chemicals by leveraging biodiversity as a tool. It also raises awareness of sustainable agricultural development within the community, in line with Goal 12 (Responsible Consumption and Production) and Goal 15 (Life on Land; UNESCO, 2024).

4. Conclusion

The development of a learning unit to promote biodiversity utilization in agricultural ecosystems resulted in a successful educational framework, integrating classroom learning with practical, community-based knowledge. The learning units focused on biodiversity management in local agricultural ecosystems. The study demonstrates that involving cultivators and local agricultural experts in the educational process not only enhances students understanding of biodiversity but also encourages sustainable agricultural practices. The results indicated significant improvement in both teachers' teaching methodologies and students' learning outcomes, particularly in their ability to manage biodiversity in agricultural ecosystems. This research aligns with the SDG Goals, particularly Goal 4 (Quality Education), Goal 12 (Responsible Consumption and Production) and Goal 15 (Life on Land) by fostering sustainable agricultural practices and integrating them into local educational frameworks.

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Authors' contributions

The study design and revisions were conducted by Phruek Jirasatayaporn, Waraporn Srisupan, Shutima Saeng-ngern, and Sansanee Choowaew. Data collection responsibilities were assigned to Phruek Jirasatayaporn, who also drafted and revised the manuscript. All authors have reviewed and approved the final manuscript. The primary responsibility for coordinating the publication of this research was assigned to Phruek Jirasatayaporn by the research team.

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Competing interests

The authors certify that they have no financial or other conflicts of interest that could influence this study.

Informed consent

Obtained.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

References

Ataei, P., Sadighi, H., Chizari, M., Aenis, T., Chizari M., & Abbasi, E. (2021). Discriminant analysis of the participated farmers' characteristics in the conservation agriculture project based on the learning transfer system. *Environment, Development and Sustainability*, *23*(1), 291–307. https://doi.org/10.1007/s10668-019-00580-5

Bareille, F., & Letort, E. (2018). How do farmers manage crop biodiversity? A dynamic acreage model with productive feedback. *European Review of Agricultural Economics*, *45*(4), 617–639. https://doi.org/10.1093/erae/jby011

Burel, F., Aviron, S., Baudry, J., Féon, V. L., & Vasseur, C. (2013). The structure and dynamics of agricultural landscapes as drivers of biodiversity. In B. Fu & B. Jones (Eds.), *Landscape ecology for sustainable environment and culture* (pp. 285–308). Springer. https://doi.org/10.1007/978-94-007-6530-6_14

Christ, L., Hahn, M., Sieg, A.-K., & Dreesmann, D. C. (2022). Be(e) engaged! How students benefit from an educational citizen science project on biodiversity in their biology classes. *Sustainability*, *14*(21), 14524. https://doi.org/10.3390/su142114524

Crofts, R. (2014). Promoting geo-diversity: Learning lessons from biodiversity. *Proceedings of the Geologists' Association*, *125*(3), 263–266. https://doi.org/10.1016/j.pgeola.2014.03.002

Fischera, L. K., Brinkmeyer, D., Karle, S. J., Cremer, K., Huttner, E., Seebauer, M., … Kowarik, I., (2019). Biodiverse edible schools: Linking healthy food, school gardens and local urban biodiversity. *Urban Forestry & Urban Greening*, *40*, 35–43. https://doi.org/10.1016/j.ufug.2018.02.015

Goldman, D., & Alkaher, I. (2024). Cultivating environmental citizenship: Agriculture teachers' perspectives regarding the role of farm-schools in environmental and sustainability education. *Sustainability*, *16*(16), 6965. https://doi.org/10.3390/su16166965

Gough, A. (2017). Educating for the marine environment: Challenges for schools and scientists. *Marine Pollution Bulletin*, *124*(2), 633–638. https://doi.org/10.1016/j.marpolbul.2017.06.069

Gurung, B., & Thapa, A. (2023). Exploring the impact of community engagement, including mental health, on the efficacy of environmental education and biodiversity conservation: A systematic literature review. *Journal of Empirical Social Science Studies*, *7*(4), 16–50. Retrieved from https://publications.dlpress.org/index.php/jesss/article/view/40

Hails, S. (2018). Educational benefits of wetlands. In C. M. Finlayson et al. (Eds.), *The wetland book* (pp. 244, 1363–1368). Springer. https://doi.org/10.1007/978-90-481-9659-3_244

Hayat, M. S., Rustaman, N. Y., Rahmat, A., & Redjeki, S. (2018). Profile of life-long learning of prospective teacher in learning biology. *Journal of Physics: Conference Series*, *1157*(2) https://doi.org/10.1088/1742-

6596/1157/2/022083

Hunter, J., Syversen, K. B., Graves, C., & Bodensteiner, A. (2020). Balancing outdoor learning and play: Adult perspectives of teacher roles and practice in an outdoor classroom. *The International Journal of Early Childhood Environmental Education*, *7*(2), 34–50.

Id Babou, S., Selmaoui, S., Alami, A., Benjelloun, N., & Zaki, M. (2023). Teaching biodiversity: Towards a sustainable and engaged education. *Education Sciences*, *13*(9), 931. https://doi.org/10.3390/educsci13090931

Ince, Z., & Şahin, V. (2021). An investigation on the scope of the concept of biodiversity in Turkey at high school geography curriculum. *European Journal of Education Studies*, *8*(1), 347–351. https://doi.org/10.46827/ejes.v8i1.3544

Jiméneza, A., Díaz, M. J., Monroe, M. C., & Benayas, J. (2015). Analysis of the variety of education and outreach interventions in biodiversity conservation projects in Spain. *Journal for Nature Conservation*, *23*, 61–72. https://doi.org/10.1016/j.jnc.2014.07.002

Johnson, D., Duke, G., Irvine, P., Kaminski, D., Boldt, J., Wismath, S., … Heaton, T. (2010). A multi-level system for delivering biodiversity knowledge, data analysis and pest management recommendations to growers, for environmentally sustainable crop protection. *Procedia Environmental Sciences*, *2*, 1163–1168. https://doi.org/10.1016/j.proenv.2010.10.125

Kimble, G. (2014). Children learning about biodiversity at an environment centre, a museum and at live animal shows. *Studies in Educational Evaluation*, *41*, 48–57. https://doi.org/10.1016/j.stueduc.2013.09.005

Lago, M., Boteler, B., Rouillard, J., Abhold, K., Jähnig, S. C., Iglesias-Campos, A., … McDonald, H. (2019). Introducing the H2020 AQUACROSS project: Knowledge, assessment, and management for AQUAtic biodiversity and ecosystem services aCROSS EU policies. *Science of the Total Environment*, *652*, 320–329. https://doi.org/10.1016/j.scitotenv.2018.10.076

Laurett, R., Paço, A., & Mainardes, E. W. (2021). Sustainable development in agriculture and its antecedents, barriers and consequences—An exploratory study. *Sustainable Production and Consumption*, *27*, 298–311. https://doi.org/10.1016/j.spc.2020.10.032

Li, P., Chen, Y., Hu, W., Li, X., Yu, Z., & Liu, Y. (2019). Possibilities and requirements for introducing agri-environment measures in land consolidation projects in China: Evidence from ecosystem services and farmers' attitudes. *Science of the Total Environment*, *650*, 3145–3155. https://doi.org/10.1016/j.scitotenv.2018.10.051

Luangduangsitthideth, O., Limnirankul, B., & Prathanthip Kramol, P. (2019). Farmers' knowledge and perceptions of sustainable soil conservation practices in Paklay district, Sayabouly province, Lao PDR. *Kasetsart Journal of Social Sciences*, *40*(3), 650–656. https://doi.org/10.1016/j.kjss.2018.07.006

Malcom, S. M. (2001). Education and biodiversity. In S. A. Levin (Ed.), *Encyclopedia of biodiversity* (Vol. 2, pp. 383–394). Elsevier. https://doi.org/10.1016/B0-12-226865-2/00094-8

McGibbon, C., & Belle, J. V. (2015). Integrating environmental sustainability issues into the curriculum through problem-based and project-based learning: A case study at the University of Cape Town. *Current Opinion in Environmental Sustainability*, *16*, 81–88. https://doi.org/10.1016/j.cosust.2015.07.013

Meekaew, N., & Ketpichainarong, W. (2018, July 8–13). *An augmented reality to support mobile game-based learning in science museum on biodiversity* (pp. 250–255). 7th International Congress on Advanced Applied Informatics. IEEE. https://doi.org/10.1109/IIAI-AAI.2018.00055

Miller, E. C., Severance, S., & Krajcik, J. (2021). Motivating teaching, sustaining change in practice: Design principles for teacher learning in project-based learning contexts. *Journal of Science Teacher Education*, *32*(7), 757–779. https://doi.org/10.1080/1046560X.2020.1864099

Mumpuni, K. E., Susilo, H., Rohman, F., & Ramli, M. (2022). Designing a module for learning plant biodiversity: An effort for conservation of local wisdom. *Biosfer: Jurnal Pendidikan Biologi*, *15*(1), 85–96. https://doi.org/10.21009/biosferjpb.22663

Nuraeni, H. (2018). Traditional knowledge of medicinal plants for health of women in Cibodas Village Lembang Subdistrict West Bandung Regency and their potency to development of biodiversity education. *Journal of Physics Conference Series*, *1157*(2), 022115. https://doi.org/10.1088/1742-6596/1157/2/022115

Ontario EcoSchools. (2019). *Biodiversity education factsheet*. Retrieved from https://www.ontarioecoschools.org/wp-content/uploads/2015/09/Biodiversity_Factsheet.pdf

Pedler, M., Yeigh, T., & Hudson, S. (2020). The teachers' role in student engagement: A review. *Australian Journal of Teacher Education*, *45*(3). https://doi.org/10.14221/ajte.2020v45n3.4

Pinkerton, M. G., Thompson, S. M., Nicole, A., Casuso, N. A., Hodges, A. C., & Leppla, N. C. (2019). Engaging Florida's youth to increase their knowledge of invasive species and plant biosecurity. *Journal of Integrated Pest Management*, *10*(1), 1–7. https://doi.org/10.1093/jipm/pmy019

Sadik, F., & Sadik, S. (2014). A study on environmental knowledge and attitude of teacher candidates. *Social and Behavioral Science*, *116*, 2379–2385. https://doi.org/10.1016/j.sbspro.2014.01.577

Schaal, S., Matt, M., & Grübmeyer, S. (2012). Mobile learning and biodiversity—bridging the gap between outdoor and inquiry learning in pre-service science teacher education. *Procedia–Social and Behavioral Sciences*, *46*, 2327–2333. https://doi.org/10.1016/j.sbspro.2012.05.479

Selby, D., & Kagawa, F. (2018). Archipelagos of learning: Environmental education on islands. *Environmental Conservation*, *45*(2), 137–146. https://doi.org/10.1017/S0376892918000097

Silici, L., Rowe, A., Suppiramaniam, N., & Knox, J. W. (2021). Building adaptive capacity of smallholder agriculture to climate change: Evidence synthesis on learning outcomes. *Environmental Research Communications*, *3*(12), 122001. https://doi.org/10.1088/2515-7620/ac44df

Singh, H. R., & Rahman, A. R. (2012). An approach for environmental education by non-governmental organizations (NGOs) in biodiversity conservation. *Procedia–Social and Behavioral Sciences*, *42*, 44–152. https://doi.org/10.1016/j.sbspro.2012.04.175

Slick, K., & Tewell, M. (2021). Forging the farm-to-school connection: Articulating the vision behind food-based environmental education at The Dalton School. In I. DeCoito, A. Patchen, N. Knobloch & L. Esters (Eds.), *Teaching and learning in urban agricultural community contexts* (pp. 159–177). Springer, Cham. https://doi.org/10.1007/978-3-030-72888-5_9

Slimi, C., Prost, M., Cerf, M., & Prost, L. (2021). Exchanges among farmers' collectives in support of sustainable agriculture: From review to reconceptualization. *Journal of Rural Studies*, *83*, 268–278. https://doi.org/10.1016/j.jrurstud.2021.01.019

Solv, A., Jabran, K., & Farooq, M. (2023). Curriculum transformations and alternative pedagogical approaches for sustainable agriculture and environment. *International Journal of Agriculture & Biology*, *30*(4), 242–252. https://doi.org/10.17957/IJAB/15.2081

Sonko, S., Maksymenko, N., Vasylenko, O., Chornomorets, V., & Koval, I. (2021). Biodiversity and landscape diversity as indicators of sustainable development. *E3S Web of Conferences*, *255*, 01046. https://doi.org/10.1051/e3sconf/202125501046

Sørensen, L. B., Germundsson, L. B., Hansen, S. R., Rojas, C., & Kristensen, N. H. (2021). What skills do agricultural professionals need in the transition towards a sustainable agriculture? A qualitative literature review. *Sustainability*, *13*(24), 13556. https://doi.org/10.3390/su132413556

The Food and Agriculture Organization (FAO). (2013). *Fast facts: The state of the world's land and water resources (SOLAW)—Managing systems at risk.* Retrieved from http://www.fao.org/docrep/017/i1688e/i1688e00.htm

UNESCO. (2024). *The sustainable development goals report 2024*. UNESCO Education Sector. Retrieved from https://unstats.un.org/sdgs/report/2024/The-Sustainable-Development-Goals-Report-2024.pdf

Wilson, J. R., & Monroe, C. M. (2005). Biodiversity curriculum that supports education reform. *Applied Environmental Education and Communication*, *4*(2), 125–138. https://doi.org/10.1080/15330150590934552

Yli-Panula, E. (2018). Teaching methods in biology promoting biodiversity education. *Sustainability*, *10*(10), 3812. https://doi.org/10.3390/su10103812