

High School Students' Competency Development in Ecological Soil Conservation through Mentoring Program

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ABSTRACT

Addressing soil degradation, this research examined the development process of undergraduate student mentors and their learning management process in ecological soil conservation. From purposive sampling, the study involved 65 participants, including mentors, mentees, a lecturer, teachers, and school administrators in Thailand. Data from the knowledge test, skill assessments, and reflection were analyzed using a dependent *t*-test, descriptive statistics, and content analysis. Based on the results, the mentors' pedagogical content knowledge had developed through reflections. The program significantly enhanced mentees' knowledge ($\bar{x} = 6.89$, S.D. = 0.75 for the school with an agricultural major available; $\bar{x} = 5.52$, S.D. = 0.77 for the school with a home economics class available) at $p < .05$, including a high level of skills and bridging generational gaps. Globally, this mentoring program provides educators with a context-responsive strategy for implementing education for sustainable development among youth across Asia and other developing regions.

Keywords: Competency development, ecological soil conservation, mentoring program

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Introduction

Soil degradation can occur from the intensive application of chemical inputs or excessive tillage. Synthetic fertilizer application is expected to increase 50% from the 2012 level by 2050 (Menegat et al., 2022). Moreover, this excessive application can negatively impact the environment and living organisms, leading to soil acidification (Zhang et al., 2022), algal blooms (Liu et al., 2021), global warming due to greenhouse gases (e.g., nitrous oxide) (Abdo et al., 2025), and health issues (e.g. carcinogens) (Tagkas et al., 2024). Thus, they contribute to soil degradation and other adverse environmental impacts in the short term and long term. Furthermore, excessive tillage leads to compacted soil, inhibiting root growth, water retention, and aeration (Gliessman, 2014). Therefore, soil degradation is a major problem.

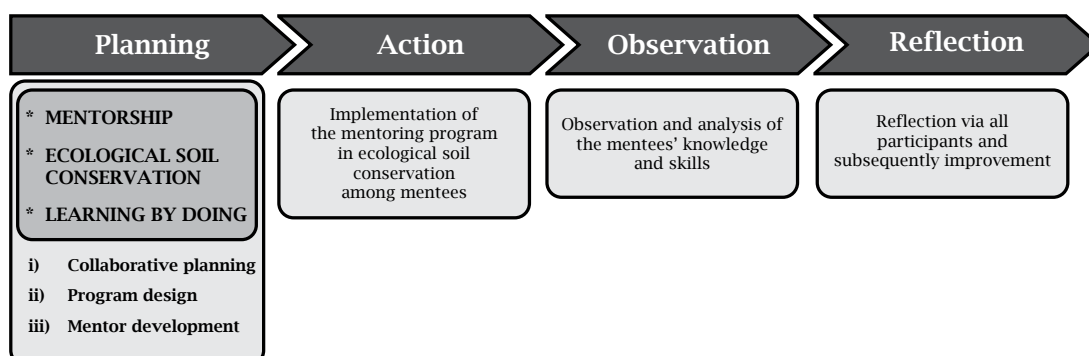
Ecological soil conservation is fundamental to achieving sustainable agriculture and is recognized as an important component of the United Nations Sustainable Development Goals (SDGs), particularly SDG15, which focuses on protecting terrestrial ecosystems, including soil and the restoration

of degraded land (United Nations, 2015). Authors, Qin et al. (2021) explained that food safety is free of contamination. Furthermore, plants cultivated in healthy soil grow well and remain strong, protecting themselves from adverse environments (Alyokhin et al., 2020).

For the above reasons, education is one approach to promote ecological soil conservation. The “learning by doing” approach, proposed by Dewey (1938), is an effective method that enables students to apply ecological soil conservation principles through hands-on experiences. High school students will be the next generation responsible for sustainable agriculture; thus, these hands-on activities will help connect them. Mentorship has been reported to be essential for developing knowledge and skills (Lim et al., 2022). The age difference between undergraduate student mentors and high school student mentees reduces the generational gap. However, a significant gap persists in the integration of ecological soil conservation through a mentoring framework. Additionally, evaluations involving reflections from multiple participants are less frequently addressed in current literature. Therefore, a program should be studied for extracurricular activities.

Figure 1

Research Framework



This research focused on the development of mentors in learning management through the implementation of mentorship (Kram, 1983), learning-by-doing (Dewey, 1938), and ecological soil conservation principles (Alyokhin et al., 2020; Gliessman, 2014). The activities were planned collaboratively with all participants. Training and reflection were conducted among mentors. The improved activities were subsequently implemented with mentees, and the mentoring program was evaluated through triangulation. The research framework is presented in Figure 1.

Literature Review

Ecological soil conservation

Ecological soil conservation approaches were reported by Alyokhin et al. (2020). Conservation tillage can reduce soil degradation and enhance the abundance of natural enemies (Lu et al., 2022). Soil organic amendments increase soil biodiversity, thereby enhancing food web complexity, while more complex food webs increase the abundance of natural enemies (Li et al., 2021). Additionally, organic matter can provide natural fertilizers to soils through microbial activities (Li et al., 2023). Furthermore, microbes can synthesize secondary metabolites to improve soil structure (Mahmood et al., 2021). Agricultural waste mulches can conserve moisture and temperature and reduce soil degradation (El-Beltagi et al., 2022). They are widely used to manage weeds. Lastly, microbial activity can convert them into nutrients and plant growth promoters. A cover crop greatly reduces soil erosion, enhances nitrogen fixation, retains water and moisture, and suppresses weeds, as well as increasing soil biodiversity. Reduced inputs of synthetic fertilizers are beneficial, since

intensive use can degrade soil health in the long term and leach into natural water resources, causing eutrophication that, in turn, produces algal blooms. Algal blooms depleted dissolved oxygen and led to declines in underwater organisms (Liu et al., 2021). Furthermore, excessive use of synthetic fertilizers can increase nitrous oxide emissions, thereby contributing to global warming (Abdo et al., 2025). The use of agricultural microbes is essential for sustainable agriculture, as they provide various benefits. For example, *Rhizobium* sp. serves as a biological fertilizer. Regarding biological control, *Trichoderma* sp. is an example.

Learning by doing

The “learning by doing” approach, a highly effective method proposed by Dewey (1938), allows learners to engage with content through practical experiences. Several research studies have supported this method. Demirhan and Sahin (2021) reported that hands-on activities enhance participants’ academic achievement scores compared with the traditional teaching method. Similarly, hands-on activities have been shown to significantly enhance learners’ acquisition of science knowledge. For instance, 15 hands-on activities implemented by Yilmaz et al. (2024) demonstrated that practical engagement effectively elevated students’ motivation for science.

Mentorship

Kram (1983) conceptualized mentorship as one in which the mentor offers support and guidance to the mentee. The mentoring program is recognized as an effective educational tool for transferring knowledge and skills from more experienced mentors to mentees. The research conducted by Lim et al. (2022) demonstrated that

mentor support within academia is significant for mentees (nursing students). Learning in mentoring programs can be accessible. Furthermore, the mentoring program can influence the sharing of knowledge, skills, experiences, and beliefs in the science, technology, engineering, and mathematics (STEM) area (Rockinson-Szapkiw & Wendt, 2021). In addition, the age proximity between mentors and mentees reduces the generational gap.

Research Questions/Objectives

The research objectives were:

1. To describe the development process of undergraduate student mentors in learning management within the context of ecological soil conservation.
2. To describe the learning management process of undergraduate student mentors within the context of ecological soil conservation.

The research questions were:

1. What are the crucial components in the development process of undergraduate student mentors in learning management within the context of ecological soil conservation for high school student mentees?
2. How are the learning management processes of undergraduate student mentors within the context of ecological soil conservation?

Methodology

Participants: Sixty-five participants comprised eight undergraduate student mentors, 52 mentees (22 high school students from Krap Yai Wong Kusonkit Phitthayakhom School in Ratchaburi Province, Thailand, where an agricultural major is offered (AMS), and 30 high school students from Salatuak Wittaya School in Nakhon Pathom Province, Thailand, where a home economics class is available (HCS)), one lecturer, two teachers, and two school directors. Mentors were purposively selected based on specific criteria. They were fourth-year undergraduate students and were majoring in Agricultural and Environmental Education. These students had completed courses including agricultural sciences and learning management, with a focus on ecological soil conservation and education. Eight mentors were selected through volunteer sampling. Additionally, mentees were purposively selected. They were studying agriculture and home economics. These students attended schools near Kasetsart University's Kamphaeng Saen Campus in Thailand.

Procedure: An action research design was adopted for this study. The detail was described below.

Planning: Ecological soil conservation, mentorship, learning by doing, and the selected school context were documented. Participants engaged in focus group discussions and developed soil conservation activities through the undergraduate student mentoring program. All activities were approved by experts. Mentors were trained in ecological soil conservation principles, practical skills, teaching, and mentorship. Subsequently, mentors demonstrated teaching to the lecturer, and the lecturer conducted reflections for improvement.

Action: The mentoring program was implemented among mentees. Mentors conducted activities once a week for three hours over seven weeks, facilitating mentees' understanding of the theory and practice of ecological soil conservation.

Observation: The program's implementation was observed. Pre- and post-tests were administered to measure changes in students' knowledge of ecological soil conservation, and dependent t-tests were used to analyze the data. In addition, mentees' practical skills were observed. The program was evaluated using descriptive statistics.

Reflection: A focus group session was conducted to reflect on the learning experience. This evaluation provided qualitative feedback on the program to refine the learning management process before implementation at another school.

Research instruments: The research instruments were a semi-structured interview form, the ecological soil conservation knowledge tests, the skill observation form, the satisfaction evaluation form, and the reflection form. Experts approved the instruments for

content validity. The item objective congruence (IOC) index ranged from 0.67 to 1.00. The tests were analyzed for test-retest reliability using the Pearson Correlation Coefficient ($r = 0.93$ and $.91$), and the rubric assessment was employed for evaluation, while the skill observation form was analyzed using the rubric assessment. The reflection was evaluated using content analysis. The thematic coding was analyzed during the Reflect phase of the Plan-Act-Observe-Reflect paradigm.

Findings and Discussion

The development process of undergraduate student mentors in learning management within the context of ecological soil conservation.

Based on focus group discussions, mentors aim to translate the principle of ecological soil conservation into practical application. An academic partnership had been established in which the schools served as a living laboratory. The activities were designed for the school context. It may be conducted as an extra-curricular activity. This initiative aligns with the SDGs related to Quality Education, Climate Action, and Life on Land. Examples of reflection are presented in Table 1.

Table 1

Reflection on the design of the mentoring program by all participants

Participants	Reflection
AMS school director	<i>"...Our school policy focused on the development of various learning management and this activity may be fit in our school..."</i>
HCS school director	<i>"...I expect this will be an academic partnership. Mentors can inspire students and the students will be engaged through experiential learning..."</i>
AMS teacher	<i>"...Our school has integrated farming area. However, the analysis of soil and soil conservation remains insufficiently emphasized...."</i>

HCS teacher	<i>"...Although our school's agricultural area is inconvenient, we can consider utilizing it for pot gardening for this activity..."</i>
Mentors	<i>"...I will digest ecological soil conservation knowledge before guiding it to mentees. Furthermore, I will implement a hands-on activity similar to the one I used when I learned a farming subject..."</i>
Lecturer	<i>"...I would like to develop mentors in ecological soil conservation, both a theoretical and a learning-by-doing approach. I emphasize ecological soil conservation because it aligns with SDG-4 Quality Education, SDG-13 Climate Action, and SDG-15 Life on Land..."</i>

Table 2

Schedule of ecological soil conservation activities through the mentoring program

Week	Learning base	Activity
1 (3 hours)	Knowledge gained on ecological soil conservation	1. A pretest was conducted among the mentees. 2. Mentors gave ecological soil conservation lectures to mentees via slide presentations. 3. Mentors used the Kahoot for the gamification of ecological soil conservation content.
5-6 (2 hours)		4. Mentors gave ecological soil conservation lectures to mentees via videos.
2 (3 hours)	Selecting optimal soil Soil testing	1. Mentors guided optimal soil selection for planting. 1. Mentors guided mentees in soil testing for analysis of nitrogen-phosphorus-potassium (N-P-K) content and pH.
3 (3 hours)	Conserving soil	1. Mentors demonstrated to mentees in conserving soil approaches via learning by doing. I. Conservation tillage II. Application of organic soil amendments III. Application of mulches IV. Reduced inputs of synthetic fertilizers V. Application of agricultural Microbes
4-6 (7 hours)		2. Mentees performed conserving soil approaches via learning by doing.
7 (1 hours)		3. Mentees harvested vegetables from plants through ecological soil conservation methods and provided them to their families.
7 (2 hours)	-	1. A posttest was conducted among the mentees. 2. The reflections were held with the mentors, the mentees, the teachers, and the school directors.

**The mentoring program was observed by the participants. The mentees care for the vegetables daily, following the mentor's suggestion via an online application.*

Both theoretical and feedback analysis indicated that the mentoring program should be selected to promote ecological soil conservation among high school student mentees. This program facilitated the transfer of ecological soil conservation knowledge and skills through hands-on activities. The approved mentoring program consisted of theoretical lectures and practical activities, as shown in Table 2.

According to the lecturer's reflection on the mentors' demonstrated teaching, the mentors could connect ecological soil conservation principles and practices. The learning media was easy to understand, featuring a well-designed presentation and full content. The Living Soil video was cleared for the study of the soil below. Furthermore, the game was attractive. Personalities were good, but they need to be more confident with a broad background of agricultural and environmental education through experiential learning. Therefore, the

mentors practiced teaching multiple times before implementing the mentoring program.

The approved activities consisted of a lecture, videos, the Kahoot game, and hands-on activities, and were suitable for high school students—all activities covered knowledge and skills enhancement. Mentors were developed based on this pedagogical content knowledge (PCK). According to Kind (2009), this PCK could be utilized to enhance the development of science teachers. Moreover, encouragement from the lecturer could empower mentors in their teaching (Nikoçeviq-Kurti & Saqipi, 2022). Additionally, the practices are effective strategies for increasing confidence (Carroll et al., 2024).

The learning management process of undergraduate student mentors within the context of ecological soil conservation

The mentoring program was conducted in both schools (Figure 2) and included activities

Figure 2

The activities of the mentoring program in ecological soil conservation: The mentors delivered a lecture, engaged in gamification, and presented a video on ecological soil conservation (left figures) and its practices among the mentees (middle and right figures).



(Table 2). Based on the results of knowledge evaluation, the pre- and post-tests show statistically significant improvements in the mentee's knowledge of ecological soil conservation (Table 3). The average post-test score (AMS $\bar{x}$ = 6.89, S.D. = 0.75; HCS $\bar{x}$ = 5.52, S.D. = 0.77) are significantly higher than the pre-test score (AMS $\bar{x}$ = 4.87, S.D. = 1.28; HCS $\bar{x}$ = 2.35, S.D. = 0.99) in both schools ($p < .05$). This indicates that the program increased high school students' knowledge of ecological

soil conservation at either the AMS or HCS level.

The skills assessment shows that high school students had advanced beginner-level skills in ecological soil conservation (Table 4). Mentees performed soil analysis and ecological soil conservation approaches. The program's hands-on activities allowed the students to gain more experience with sustainable agricultural practices in ecological soil conservation.

Table 3

Comparisons of ecological soil conservation knowledge of high school students between pre-test and post-test in both school tests

Ecological soil conservation knowledge	N	$\bar{x}$	S.D.	t	Sig.
School where an agricultural major is available (AMS).					
Pre-test	22	4.87	1.28	6.75	.000
Post-test	22	6.89	0.75		
School where a home economics class is available (HCS).					
Pre-test	30	2.35	0.99	15.85	.000
Post-test	30	5.52	0.77		

Note: Significant at the .05 level ($p < .05$)

Table 4

Ecological soil conservation skills assessment of high school students in both schools

Ecological soil conservation skill	$\bar{x}$	S.D.	Evaluation
AMS; N=22			
1. Conservation tillage	3.00	0.00	High
2. Application of soil organic amendments and beneficial microbes	2.91	0.29	High
3. Reduced inputs of synthetic fertilizers	3.00	0.00	High
4. Application of organic mulches	3.00	0.00	High
HCS; N=30			
1. Conservation tillage	3.00	0.00	High

2.	Application of soil organic amendments and beneficial microbes	2.77	0.43	High
3.	Reduced inputs of synthetic fertilizers	3.00	0.00	High
4.	Application of organic mulches	3.00	0.00	High

Interpretation scale: Mean range 1.00-1.66 = Low; 1.67-2.33 = Moderate; 2.33-3.00 = High

Table 5

Satisfaction evaluation of mentoring program for high school students in both schools

Satisfaction evaluation	$\bar{x}$	S.D.	Meaning
AMS; N=22			
Item			
Knowledge dissemination	4.68	0.48	Highest
Question responsibility	4.77	0.53	Highest
Idea exchange	4.77	0.53	Highest
Less gap generation	4.86	0.35	Highest
Summary	4.77	0.47	Highest
HCS; N=30			
Item			
Knowledge dissemination	4.75	0.62	Highest
Question responsibility	4.59	0.65	Highest
Idea exchange	4.62	0.68	Highest
Less gap generation	4.88	0.49	Highest
Summary	4.79	0.43	Highest

Interpretation scale: Mean range 1.00-1.80 = Lowest; 1.81-2.60 = Low; 2.61-3.40 = Moderate; 3.41-4.20 = High; 4.21-5.00 = Highest

According to the satisfaction evaluation form (Table 5), high school students expressed the highest satisfaction with the mentees' knowledge dissemination, responsibility for questions, idea exchange, and the generation of fewer gaps.

Finally, all participants recorded their reflections and opinions on this mentoring program. The summarized reflections were presented, and some examples are shown in Table 6.

Mentee perspectives: The mentees gained knowledge and skills in ecological soil conservation, an understanding of university life, and the Agricultural and Environmental Education curriculum. Furthermore, they felt more confident and appreciated their relationships with their mentors.

Mentor perspectives: The mentors reflected upon enhancing their knowledge and skills, dissemination, communication, and leadership abilities. They demonstrated that the learning management should be adjusted for different

Table 6

Reflection on the implementation of the mentoring program by all participants

Core theme	Assigned codes
1. Pedagogical Adaptation and Professional Development	Instructional adjustment, context responsiveness, high preparation, empathy
Sample Qualitative Evidence	
<i>"...I adjusted the way I taught in the second school, which lacked sufficient agricultural background. I provided them with brief videos on plant care and give rewards from playing Kahoots ..."</i> (Mentor 2) <i>"...Initially, I wasn't feeling very confident about teaching, but I gave it my all with well-prepared content and practices. What mattered most to me was showing empathy to my mentees..."</i> (Mentor 1) <i>"...The mentees prepared their materials thoroughly. They demonstrate the potential to perform effectively as mentors, as evidenced by the evaluation of the reflections...."</i> (Lecturer)	
2. Competency Development and Ecological Literacy	Practical skill acquisition, soil testing, pH neutralization, and chemical fertilizer substitution
Sample Qualitative Evidence	
<i>"...I enjoy studying with our mentors. I could replace synthetic fertilizers with organic fertilizers..."</i> (AMS mentee) <i>"...I would like to learn with the mentors once again. They are kind and flexible. I like the analysis of soil nutrient content and pH. For example, if the soil is acidic and unsuitable for plants, I can add lime to neutralize the soil..."</i> (HCS mentee)	
3. Classroom Dynamics and Intergenerational gap reduction	Classroom management development, active engagement, flexible environment, age proximity
Sample Qualitative Evidence	
<i>"...The contents are very interesting. Initially, the mentors' classroom management was inadequate; however, they continuously improved as they gained more insight into their mentees' characteristics..."</i> (AMS teacher) <i>"...I think that the mentors can reduce the intergenerational gap and foster active engagement among our high school students in the extracurricular activities..."</i> (HCS teacher)	
4. Collaboration and Sustainability	Local waste utilization, extracurricular support, academic partnership
Sample Qualitative Evidence	
<i>"...I preferred the mentoring program. Recently, our school and the university provided another mentoring program in mushroom production for high school students..."</i> (AMS school director) <i>"...Due to our school's environmental policy, I would like to propose a mentoring program focused on analyzing the nutrient content in the compost produced from sugarcane leaves, a form of local agricultural waste..."</i> (HCS school director)	

mentees. They suggested that empathy for their mentees was important. They also expressed satisfaction in guiding their mentees with the ecological soil conservation approach and other personal insights.

Teacher perspectives: Teachers observed that the high school students became increasingly engaged in learning after the mentoring program. They felt that mentors brought fresh content and established senior-junior relationships in

the classroom, creating a relaxed environment. Teachers also perceived that their students' communication and interpersonal abilities improved. Furthermore, they suggested that the school's scheduling should be suitable for integrating mentoring programs.

School director perspectives: The school directors expressed that this mentoring program motivated students to study at the undergraduate level. They also observed that the mentoring program bridged the gap between high school and university life. In addition, they perceived that this program supported teachers with extracurricular activities. Both school directors expressed a need for enhanced academic collaboration between the schools and the university. From the administrators' perspective, both school directors considered other mentoring programs.

Lecturer perspectives: The characteristics of a mentor in ecological soil conservation were as follows: They should possess a broad background in related soil sciences and education, and effectively implement the pedagogical content knowledge. Furthermore, they should demonstrate practice over an extended period and exhibit empathy. Additionally, they should be adaptable for individual classrooms.

After participating in the mentoring program, mentees developed knowledge and skills in ecological soil conservation (Alyokhin et al., 2020) under the guidance of mentors. This observation represents the efficacy of integrating pedagogical tools within the mentoring program. According to studies on hands-on activities (Dewey, 1938; Demirhan & Sahin, 2021; Yilmaz et al., 2024), mentees can transition from fundamental theories to practical methodologies in ecological soil conservation. In addition, the videos and the game were used to

enhance understanding. This was supported by the research of Costley et al. (2021), who found that videos improved knowledge and skills. Furthermore, research by Dehghanzadeh et al. (2024) showed that games effectively motivated learners and improved knowledge across diverse contexts. From the qualitative reflection, the success of the mentoring program depended on the mentor development and context-responsive teaching. The mentors prepared their instruction to meet the needs of both AMS and HCS schools, drawing on their backgrounds in agricultural and environmental sciences and eco-friendly farming practices. Moreover, they were empathetic toward the mentees. Based on the mentoring framework (Kram, 1983; Lim et al., 2022; Rockinson-Szapkiw & Wendt, 2021), this mentoring initiative is crucial for fostering knowledge and skills, transferring value beliefs, and reducing intergenerational gaps.

Implications

The empirical insights from this study provide practical recommendations for ASEAN teacher education. Firstly, it offers an operational blueprint for the university to enhance community outreach. Undergraduate students can translate environmental theory into practice. Secondly, the learning-by-doing approach offers a strategy for transitioning from theoretical knowledge to practical application. Thirdly, it enables curriculum developers to establish education for sustainable development by embedding complex competencies, such as ecological soil conservation, into secondary school curricula. Lastly, it proposes a proportional weighted scoring rubric for evaluating practical competency.

Conclusion

This action research aims to study the development of the mentors and their learning management in ecological soil conservation. These findings fill a gap in the literature by providing a pedagogical framework that translates ecological theory into practice.

Regarding mentor development, the reflection advances mentors' pedagogical content knowledge. Theoretically, mentors' teaching self-efficacy is enhanced through supervisor support and repeated practice.

The effectiveness of this mentoring program within the learning management system is empirically confirmed through a triangular analysis. The statistically significant increases in mentees' knowledge ($p < .05$), and the skills are at a high level across diverse school contexts. In addition to qualitative reflections, the participants describe the program as bridging intergenerational gaps. Theoretically, the learning media and hands-on activity are optimized through the mentoring program.

In conclusion, the mentoring program effectively cultivates soil conservation literacy while bridging generational gaps. Its implications offer a transfer theory, provide a performance-based rubric assessment, and supply curriculum developers with a blueprint to operate education for sustainable development.

As researchers, we observe that the mentors adapt their teaching to different schools. Furthermore, environmental literacy will be achieved when the community is integrated into scientific practices.

A major limitation of this study is the short-term program. To address this weakness, future

research should implement long-term and expand the invention across broader school contexts.

Additionally, future research should integrate other fields of sustainable agriculture into this mentoring framework. Moreover, investigating this model in other ASEAN member nations will help establish an educational framework for sustainable development.

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