



Integrating of permaculture system with eco-gamification systems in biodiversity learning to promote SDG-12

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Article Information	Abstract
Keyword: Playing outdoors; Sustainability practices; Biological diversity; Eco-gamification Kata Kunci: Bermain di luar ruangan; Praktik keberlanjutan; Keanekaragaman hayati; Gamifikasi ramah lingkungan History: Received : 19/12/2024 Revised : 23/02/2025 Accepted : 25/02/2025 Published : 27/02/2025	The achievement of biodiversity learning in schools has only reached 60% classical completeness, with low student understanding: 10.1% demonstrated full comprehension, 48.7% experienced misconceptions, and 41.2% showed no conceptual understanding. This highlights the need to improve biodiversity education. This study aims to enhance students' understanding by integrating permaculture systems and eco-gamification into the learning process, aligning with Sustainable Development Goal (SDG) 12 on responsible consumption and production. Using a quantitative experimental design, 25 10th-grade students from a high school in Bandung were selected through cluster sampling. Data were collected via Likert scale questionnaires, expert observation sheets (0–1 scale), and direct observations. The study was conducted in three stages: preparation, implementation, and data analysis. The implementation achieved an 82% success rate (Good category), indicating high student engagement. Student responses showed 48.7% strongly agreed (Fair), 33.1% agreed (Poor), and 18.2% disagreed (Poor), reflecting varying acceptance levels. Key challenges included difficulties in memorizing scientific names and understanding <i>binomial nomenclature</i>. Enhancing strategies, such as hands-on practice and optimized gamification, is essential to maximize learning outcomes while fostering awareness of ecosystem balance. Abstrak. Pencapaian pembelajaran keanekaragaman hayati di sekolah hanya mencapai 60% ketuntasan klasikal, dengan tingkat pemahaman siswa yang rendah: 10,1% menunjukkan pemahaman penuh, 48,7% mengalami miskonsepsi, dan 41,2% tidak memahami konsep sama sekali. Hal ini menunjukkan perlunya peningkatan pendidikan keanekaragaman hayati. Penelitian ini bertujuan untuk meningkatkan pemahaman siswa dengan mengintegrasikan sistem permakultur dan eco-gamification dalam proses pembelajaran, sejalan dengan Tujuan Pembangunan Berkelanjutan (SDG) 12 tentang konsumsi dan produksi yang bertanggung jawab. Penelitian ini menggunakan desain eksperimen kuantitatif dengan melibatkan 25 siswa kelas X dari salah satu SMA di Bandung yang dipilih melalui teknik cluster sampling. Data dikumpulkan melalui kuesioner skala Likert, lembar observasi ahli (skala 0–1), dan observasi langsung. Penelitian dilakukan dalam tiga tahap: persiapan, pelaksanaan, dan analisis data. Implementasi pembelajaran mencapai tingkat keberhasilan sebesar 82% (kategori Baik), menunjukkan tingginya keterlibatan siswa. Respon siswa menunjukkan 48,7% sangat setuju (Cukup), 33,1% setuju (Kurang), dan 18,2% tidak setuju (Kurang), mencerminkan tingkat penerimaan yang bervariasi. Tantangan utama yang dihadapi adalah kesulitan dalam menghafal nama ilmiah dan memahami tata nama binomial. Oleh karena itu, peningkatan strategi seperti praktik langsung dan optimalisasi elemen gamifikasi diperlukan untuk memaksimalkan hasil belajar sekaligus meningkatkan kesadaran menjaga keseimbangan ekosistem.

A. Introduction

Indonesia is known as a country with very high biodiversity. As an archipelago that covers 1.3% of the earth's surface area, Indonesia has abundant genetic resources. In addition, Indonesia is included in the twelve centres of world biodiversity because it has the largest area in the Indomalaya region (KLH, 2014). There are 670 mammal species or about 10.5% of the world's species population; 4782 fish species or about 1.2% of the world's species population; 1711 bird species or about 15.5% of the world's species population; 755 reptile species or about 6.7% of the world's species population; and 365 amphibian species or about 4.6% of the world's species population (LIPI, 2020). Indonesia's natural plant wealth includes 30,000 plant species out of a total of 40,000 plant species (Cahyaningsih et al., 2021).

Uninterrupted biodiversity loss can lead to reduced nutrients, less wild food, poor pollination, and subordinate and less robust agricultural systems (Singh et al., 2021). Another problem is that many of the current generation or students need more knowledge about biodiversity and the environment, a misunderstanding of biodiversity and the environment, and not the optimal level of education in influencing students' knowledge of the benefits of biodiversity (Marlina, 2017). This ignorance can lead to higher vulnerability to agrochemicals, reduced access to traditional medicine, reduced opportunities for drug development, and further lead to the emergence of uncontrolled diseases (Roe et al., 2019). As a result, treatment using natural medicinal plants is becoming difficult to find, therefore students need information in the form of knowledge and skills to manage and cultivate medicinal plants. Another urgency is the continuous lack of consumption of vegetable plants among adolescents in Indonesia, which causes the risk of future health problems such as degenerative diseases (Ani & Masnina, 2022). This research is motivated to solve the problem of biodiversity in horticultural plants, which are an important component in maintaining the balance of the ecosystem and becoming a human food resource. With its existence threatened by various challenges, such as limited knowledge about the decline in the production of medicinal plants, the biodiversity of horticultural plants is threatened (Buku Atap Hortikultura, 2023), low consumption of vegetables among students (Widani, 2019), and instability of vegetable and fruit supply is an issue under the SDG-12 target in section 12.7 on promoting sustainable public procurement practices, by national policies and priorities. (United Nations, 2021).

Based on observations of biology learning in schools, students' achievements in the biodiversity material only reached 60% classical completeness (Ulimaz, 2015; Anwar & Rahmayanti, 2021). This result indicates that the applied learning approach has not been fully effective in improving students'

understanding. A study in Turkey found that although the country has a very rich biodiversity, environmental education there is not based on biodiversity, making learning less contextual for students (Erten, 2021). To address this issue, this study proposes a permaculture system assisted by eco-gamification as a more effective learning approach. Permaculture is a method that emphasizes the protection and sustainable utilization of biodiversity while promoting a balance between ecological, social, and cultural aspects. In an educational context, permaculture not only introduces theoretical ecological concepts but also emphasizes environmental concern, equality, fair treatment of humans, and working with rather than against nature (Genus et al., 2021).

Therefore, permaculture serves as an alternative approach to enhance students' comprehension of biodiversity and foster their ecological awareness (Henfrey, 2017). It helps students grasp the importance of maintaining biodiversity through sustainable agricultural practices, waste reduction, and efficient resource use patterns (Lloyd, 2017). Aligning with SDG-12's goal of ensuring sustainable consumption and production. However, challenges remain in engaging students and actively making them understand the complexity of this subject matter. To overcome these challenges, the eco-gamification approach, which integrates game elements with environmental learning, is considered an innovative solution. This approach is expected to increase students' interest and motivation to learn and apply their knowledge in real life (Ulimaz et al., 2024). However, the implementation of eco-gamification in formal education, particularly in biology courses, remains rare. Most studies on gamification have been conducted within classroom settings, and very few have explored its application in outdoor or experiential learning environments (Brady & Andersen, 2021; Su & Cheng, 2015). According to the Australian Government Department of Education (2022), game-based learning places children at the center of educational experiences to expand and enrich their understanding. This is supported by the United Nations Convention on the Rights of the Child (United Nations, 2021).

Additionally, eco-gamification can contribute to sustainable consumption, and by extension, the United Nations SDG-12 on Responsible Consumption and Production (Lim et al., 2025). By applying these concepts in learning, students not only gain knowledge about biodiversity but are also encouraged to take an active role in sustainable practices, contributing to long-term environmental stewardship. Therefore, the integration of biodiversity learning in grade X through the permaculture system assisted by eco-gamification aims to increase students' understanding of the importance of biodiversity and encourage real action in its conservation to support SDG-12.

B. Material and method

This study uses a quantitative research approach categorized as experimental research. The target population consisted of 25 students of grade X of SMA Laboratorium Perpilotan UPI, selected using cluster sampling, a technique based on existing class groups (Jeelani et al., 2018). The research procedure consisted of three stages: 1) Preparation Stage; This stage involves the implementation of literature studies and preparation of permaculture gardens, which took place from June 2024 to October 2024 at the UPI Botanical Garden as part of outdoor learning activities. In addition, an analysis of biology learning in an

independent curriculum was carried out to align the learning process with curriculum objectives. 2) Implementation Stage; Learning activities focused on biodiversity material and were carried out for two sessions in the botanical garden. Students were involved in activities based on the approved learning modules and student worksheets. The study was conducted by observing the ongoing learning activities. The observation sheets that had been prepared in advance were used to record the learning process. The observation sheets were arranged in the form of a checklist implementation aspects containing the implementation of the learning process which can be seen in Table 1.

Table 1 Implementation observation questionnaire

No.	Aspect
1.	Students greet the teacher, say a prayer, and wait for attendance.
2.	Students follow the teacher's instructions to form groups.
3.	Students receive information from the teacher about the posts in the UPI botanical garden (Permaculture).
4.	Students use the student worksheet for learning activities.
5.	Students listen to the gamification mechanism for the activity.
6.	Students utilize the permaculture learning posts as learning resources through gamification strategies.
7.	Students complete all learning activities in the student worksheet.
8.	Students learn in a conducive classroom environment during the lesson.
9.	Students follow the time allocation stated in the teaching module.
10.	Students and teacher conduct a learning evaluation together.
11.	Students and teacher conclude with reflections, messages, and impressions at the end of the lesson.

Table 2 Percentage interpretation

Percentage (%)	Category
86-100	Very good
75-85	Good
60-74	Fair
55-59	Less
≤54	Very poor

(Source: Purwanto, 2012)

Learning observations were designed to capture direct student involvement and the application of critical thinking skills during the learning process. At the end of the learning process, students were given a response questionnaire to evaluate their perceptions of the learning activities carried out by the teacher. This questionnaire aimed to collect student feedback on the learning approach, clarity of the material, and their overall experience during the session. At the Data Processing Stage (3), the observation sheet was analyzed using the Guttman scale (0-1), where a score of 0 indicates that the process was not implemented, and a score of 1 indicates that the process was fully implemented (Sugiyono, 2014). Then, the data were analyzed using Formula 1 and interpreted as a percentage in Table 2.

$$NP = \frac{R}{SM} \times 100\% \dots \dots \dots \text{Formula 1}$$

Description:
NP = Percentage of ability
R = Score obtained
SM = Maximum score

The data analysis technique used to assess student responses is by using a questionnaire instrument displayed in Table 3 based on a Likert scale. The scale consists of four response categories, namely SA (Strongly Agree), A (Agree), D (Disagree), and SD (Strongly Disagree) (Riduwan, 2015). Then the data is analyzed using Formula 2 by Arifin (2010) and interpreted in the form of a percentage in Table 4.

$$P = \frac{\Sigma R}{N} \times 100\% \dots \dots \dots \text{Formula 2}$$

Description:
P = Percentage or proportion
 ΣR = Total number of response scores
N = Total number of respondents.

Table 3 Student response questionnaire

No.	Statement
1.	Learning biodiversity through eco-gamification in the permaculture system helps me understand biodiversity concepts better.
2.	I find it easier to recognize and classify living organisms after participating in this learning process.
3.	This learning method helps me understand the concept of <i>binomial nomenclature</i> (scientific names of living organisms) more clearly.
4.	I can remember and mention the scientific names of various species after this learning experience.
5.	I am aware of the challenges in maintaining biodiversity, such as deforestation and climate change.
6.	I understand how the permaculture system can be a solution to maintaining ecosystem balance and improving environmental sustainability.
7.	Eco-gamification makes biodiversity learning more engaging and increases my motivation to learn.
8.	I understand the importance of balance between producers, consumers, and decomposers in the ecosystem after learning through this system.
9.	I can relate biodiversity concepts learned in class to environmental issues occurring around me.
10.	This learning method provides insights into various solutions for biodiversity conservation, such as sustainable farming practices and ecosystem rehabilitation.
11.	I would like this learning method to be implemented in other biology lessons because it is effective and enjoyable.

Table 4 Percentage interpretation

Percentage range	Category
0-10%	Very poor
11-40%	Poor
41-60%	Fair
71-90%	Good
91-100%	Excellent

(Source: Arifin, 2016)

C. Results and discussion

The data from learning observations and student responses related to biodiversity material are used to analyze students' understanding of the importance of biodiversity and encourage them to take concrete actions for its conservation in support of SDG-12. The learning process involves student visits to three stations as part of activities designed to introduce biodiversity within the permaculture system. These observations aim to assess the implementation of the activities and gather student responses regarding learning outcomes, thereby strengthening and enriching the collected data.

Analysis of the implementation of learning biodiversity material in the permaculture system with eco-gamification

The learning process at the first post, students will meet various types of flora and fauna, here students identify and inventory the flora and fauna encountered and record the scientific name of each species present. The inventory was carried out in response to the many species that are of concern and interest to students in understanding ecosystem dynamics (Genus et al., 2021). In the study of Booth-Sweeney (2017), it was emphasized that identification learning can help students make their own decisions to create a balance between a healthy ecosystem, a sustainable and equitable economy, and a fair social system for everyone.

At the second permaculture post, students explore the concept of sustainable agriculture that

integrates plants and fish in a balanced ecosystem. The aquaponic system is an integrated system between aquaculture and hydroponics where fish farming waste in the form of metabolic waste and feed waste is used as fertilizer for plants (Stathopoulou et al. 2018). In this system, plants function as biofilters so that the water that returns to the cultivation pond is already clean (Zidni et al., 2019). This hands-on learning experience allows them to understand the interdependence of these elements in maintaining sustainable consumption patterns. through the process of learning from experience and real action in seeing sustainable consumption, this reflects the principles of sustainable consumption and sustainable development (Widjajanti et al., 2014).

The third permaculture station, students explore the process of recycling organic waste through the use of Black Soldier Fly (BSF) larvae. students learn BSF farming in the waste management cycle completing the circular process where waste will provide nutrients to BSF larvae, and then the protein-rich by-products and residual frass produced can be reused as animal feed and fertilizer (Lopes et al., 2021). BSF becomes a producer by producing manure consisting of macro and micro nutrients and biostimulants, such as chitin and plant growth-promoting microbes, making it ideal for improving soil conditions and fertilizing plants that can be used in agricultural systems (Lopes et al., 2021; Khayrova et al., 2019; Kebli & Sinaj, 2017). This learning indirectly promotes SDG-12 which basically calls for efficient use of natural resources, reduction of food and other waste

and adoption of more sustainable practices (Chan et al., 2018).

Activities at each post are combined with playing in nature or eco-gamification. With the Guess me game, which is a word game where students look for the names of flora or fauna based on clues or instructions on the barcode that have been distributed in various places and then answer with the appropriate name. Teaching words by guessing in games can be interesting, fun, and exciting for students. Such activities encourage a positive learning attitude towards language learning and encourage learners to use the linguistic knowledge they have acquired to communicate (Hasanah., 2021). For more details, Figure 1 presents documentation of student activities during the teaching and learning process in the Eco Gamification-assisted permaculture system.

The biodiversity learning system in permaculture is designed as an educational resource for students to develop environmental awareness and responsibility. In this process, students learn to understand their role as producers who maintain the balance of the ecosystem and as responsible consumers in utilizing natural resources. The study results of Chawla (2020) showed that active involvement in activities such as species identification, environmental observation, reflection on the beauty of nature, and ecosystem exploration significantly increased ecological awareness and pro-environmental behavior in students, which is in line with the learning objectives in the permaculture system. The gamification approach in learning can increase environmental awareness and encourage sustainable behavior, including recycling habits as an act of responsible consumption (Hsu & Chen, 2021). Therefore, this learning system has great potential in supporting the achievement of SDG-12 by encouraging more responsible consumption and production patterns and forming a generation that is aware of the importance of environmental sustainability.

Then, based on the data obtained, the implementation of student learning on the material on biodiversity in the permaculture system shows the distribution in Table 5.



Figure 1
 (A) Activities at the first post, (B) activities at the second post, and
 (C) activities at the third post

Table 5 Distribution of learning implementation

No	Aspect	Yes	No
1	Students greet the teacher, say a prayer, and wait for attendance.	✓	-
2	Students follow the teacher's instructions to form groups.	✓	-
3	Students receive information from the teacher about the posts in the UPI botanical garden (Permaculture).	✓	-
4	Students use the student worksheet for learning activities.	✓	-
5	Students listen to the gamification mechanism for the activity.	✓	-
6	Students utilize the permaculture learning posts as learning resources through gamification strategies.	✓	-
7	Students complete all learning activities in the student worksheet.	✓	-
8	Students learn in a conducive classroom environment during the lesson.	-	✓
9	Students follow the time allocation stated in the teaching module.	-	✓
10	Students and teacher conduct a learning evaluation together.	✓	-
11	Students and teacher conclude with reflections, messages, and impressions at the end of the lesson.	✓	-
Percentage of activity implementation		82%	18%
Category		Good	Very poor

The findings presented in Table 5 were obtained from direct observations made by field observers during the implementation of learning in the eco-gamification-assisted permaculture system. Observers regularly recorded student responses, levels of engagement, and challenges faced during the learning sessions. The positive response rate of 82% reflects the effectiveness of this approach, placing it in the good category based on the classification outlined in Table 2. This indicates that most of the learning activities were successfully implemented, though some areas still require improvement. Therefore, it can be concluded that permaculture can be effectively integrated into biodiversity materials to enhance students' understanding of ecosystem sustainability as responsible producers and consumers, aligning with the goals of SDG. This learning approach is also in line with Phase E of the Independent Curriculum, which highlights that all educational activities must be directed at sustainable development and the implementation of SDGs in learning practices (Ministry of Education, Culture, Research, and Technology, 2022). In this context, permaculture-based learning introduces students to the identification of plant species as part of sustainable food production, resource efficiency, and environmentally friendly agricultural practices. Although the results show the effectiveness of permaculture-based learning, observers also identified challenges in its implementation, which accounted for 18% of the total

responses. Key challenges include time allocation and classroom conditions, where learning processes sometimes go beyond the set schedule. These findings are consistent with previous research on lack of time, resources, and support; and broader changes in the education sector (Patchen et al., 2022). In addition, observer reports indicate that students face difficulties in time management, adapting to outdoor environments, managing climate change, and clothing, which are common barriers to nature-based education (Dring et al., 2020; Edwards-Jones et al., 2016; Shume & Blatt, 2019). Therefore, the implementation of Phase E and the SDGs in education, especially in the context of outdoor learning, requires a more comprehensive environmental strategy in time planning, resource management, and adaptation to ensure that sustainability goals are optimally achieved.

Analysis of student responses regarding learning the material of biodiversity in the permaculture system with eco-gamification

From the learning process, students' learning responses to the material on biodiversity in the permaculture system show the distribution in Figure 2. The analysis of student responses to biodiversity learning within the permaculture system using eco-gamification shows varying levels of acceptance. The average percentage for each response category reflects the overall effectiveness of this learning method, as presented in Table 6.

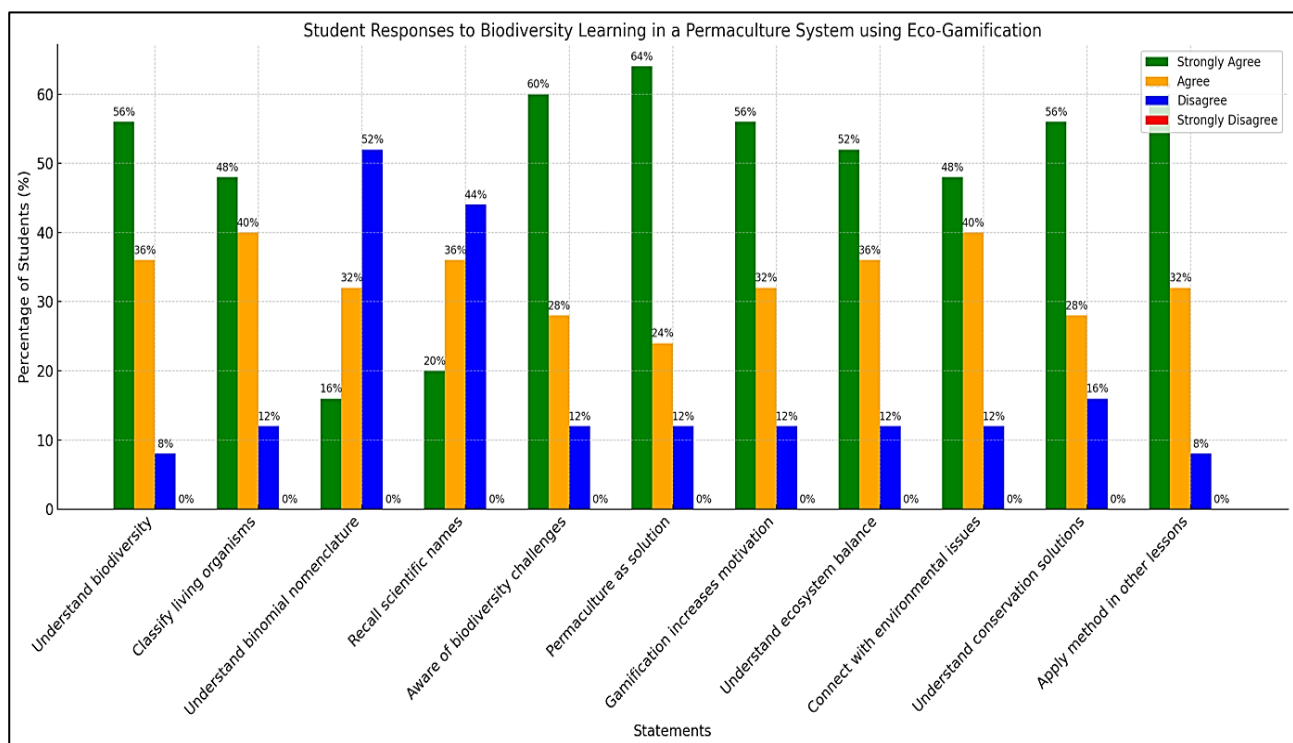


Figure 2 Distribution of student responses

Table 6 Average percentage of student responses

Response	Average percentage	Category
Strongly agree	48.7%	Fair
Agree	33.1%	Poor
Disagree	18.2%	Poor
Strongly disagree	0%	Very Poor

The data presented in Table 6 highlights the varying levels of student acceptance of biodiversity learning through the permaculture system using eco-gamification. The majority of students chose Strongly Agree (48.7%), which falls into the fair category. Although this indicates a positive trend towards the learning method, it also shows room for improvement to maximize its impact. Impacts that have not been felt by students such as direct involvement in the process of arranging elements or plants and design features in the design location that match the student's learning environment (Bradley, 2015). The Agree response (33.1%) is categorized as Poor, indicating that most students consider the approach quite effective but not entirely interesting or comprehensive. To attract students' attention, learning can be done through direct practice in the permaculture system such as planting, watering and caring for plants (Nurlaila et al., 2014; Wahidi et al., 2021). Permaculture strongly supports important skills in students such as soil preparation, water harvesting, and plant propagation, students gain practical knowledge and it is hoped that students will become very fond of nature (Rahma., 2018). Similarly, the Disagree response (18.2%), also in the Poor category, indicates that certain areas of the material are still not well perceived. Problems in remembering terminology in students can be overcome by planting plants directly, making students better understand the physical characteristics of plants to recognize the names of plant species (Stagg et al., 2024). Observing plants and animals over time or seasons will strengthen their memory (Wyner & Doherty, 2022). The more often observing the intrinsic qualities of plants contributes to their visibility and memorability, the most eye-catching or memorable plants such as plants with unusual adaptations or sensory characteristics (Nyberg & Sanders 2014).

The positive impacts of the permaculture system become clearer when examining student responses more broadly, as seen in Figure 2. As many as 56% of students stated that they strongly agreed that this approach was quite effective in attracting their interest through interactive and fun activities to understand biodiversity, and 48% of them could understand the classification of living things. The permaculture system provides information that students need, such as knowing the special characteristics of flora and fauna, understanding environmental protection, animal welfare, food quality and safety, and resource sustainability (Muhie, 2022). Additionally, knowing the form of a more ecologically harmonious environment (Khadse et al., 2021) can

encourage interest in maintaining biodiversity through agricultural techniques (Paull & Hennig, 2020).

Through this learning, 60% of students strongly agreed that they became more aware of the challenges of biodiversity, 48% Connected with environmental issues and 52% felt they understood the balance of the ecosystem better after participating in the learning process. This approach helps students understand sustainability issues, especially those related to environmental conservation and ecosystem balance, which are increasingly important in the 21st century (United Nations, 2021). Permaculture or perhaps high natural value agriculture) is an option that can be taken to understand the challenges of ecosystem services and will affect long-term biodiversity management (Oberč & Arroyo Schnell, 2020) because permaculture places social, environmental and economic emphasis on sustainable intensification (Armstrong & Kamieniecki, 2019; Cléménçon, 2021).

In this study, 64% of students also strongly agreed that permaculture is an effective solution for environmental sustainability, reflecting the relevance of permaculture education in facing real environmental challenges, and 56% of students understood conservation solutions. Several countries, such as Kenya (Rural Initiatives Development Programme, n.d.), the Philippines, and the United States (Ross, 2023), have even integrated the concept of permaculture into nature-based curricula to strengthen understanding of environmental issues related to biodiversity and conservation. Permaculture has characteristics that address various community problems (Weltin et al., 2018) through green reform techniques to build industrial systems that focus on increasing the productivity of plant diversity in the agricultural sector (Cuadros-Casanova et al., 2023), as the permaculture system is a new trend that is oriented towards nature (Dahl & Emontspool, 2021; Muhie, 2022). Production systems like this can offer many benefits in response to various community problems and have a promising future (Pretty et al., 2018). There are 56% of students who strongly agree that eco-gamification not only deepens their understanding of biodiversity but also increases their motivation and engagement. This view is in line with the opinion of Karaarslan-Semiz (2022) who emphasized the importance of building student interest in maintaining harmony between human and ecosystem systems. This understanding can be strengthened through the role of competent teachers in Education for Sustainable Development (ESD) so that the integration of permaculture with eco-gamification can encourage

active student engagement. Gamification functions as a strategy to increase participation by adopting game elements in the learning environment (Dichev & Dicheva, 2017). This can be seen from research in the field of eco-gamification showing that active involvement motivation (Pedro et al., 2015), and concern (Jia et al., 2016) are the main factors that influence the effectiveness of learning about biodiversity. A preference survey by Jang et al. (2015) found that learning aimed at increasing student interest and engagement was much more effective when using gamification elements. Gamification helps students become more enthusiastic and form environmentally friendly attitudes. Learning in the permaculture system with eco-gamification makes this learning holistic, inclusive, and democratic without limiting the level, nature, or influence of any individual's input (Henfrey, 2017). 60% of students strongly agree with applying this method in other subjects. Several countries have implemented nature-based permaculture curricula. Learning that involves permaculture focuses on environmental education, biodiversity, and ecosystem resilience, which are available for children from early childhood to high school (Minnesota Department of Education, 2021; Leopold Education Project, 2016; Project Learning Tree, 2022; Project WILD, 2018).

However, some aspects are still obstacles for students, especially in remembering and mentioning scientific names and understanding *binomial nomenclature*. As many as 48% of students stated that they disagreed with their ability to remember scientific names, while 52% of students stated that they had difficulty understanding *binomial nomenclature*, which indicates that Latin-based scientific terms are still quite an important obstacle in learning biology. Latin terminology is often unfamiliar to students, making it difficult for them to memorize (Firmanshah et al., 2020). The extensive use of scientific terms in biology is a major challenge for students (Rasyid, 2015). According to this system, there are unavoidable difficulties. For example, the same species is often given different scientific names, or previously named species are separated into two or more new species (Sigovini et al., 2016).

The urgency of research through these findings shows quite good effectiveness in learning biodiversity using the permaculture system supported by gamification. Because based on the results of the analysis, most students gave a positive response to this approach, which shows that the permaculture system is able to attract students' interest through interactive and fun activities that indirectly contribute to the achievement of SDG-12, namely trying to overcome the disruption of the economic growth cycle in resource utilization, and current environmental degradation, which has triggered unsustainable global development for decades (Küfeoğlu, 2022). Natural resource protection programs are needed and following

sustainable consumption and production is essential to achieving sustainable global development (Gasper et al., 2019). Permaculture needs a position in education that is very important for the success of cutting-edge projects, creating change, breaking away from old paradigms, learning in new ways and using ecological management practices and local adaptive solutions to produce resilient communities (Carbonell, 2023).

D. Conclusion

Permaculture-based learning with gamification provides students with hands-on experiences in identifying flora and fauna, understanding sustainable agriculture, and managing organic waste. Observations indicate that this method effectively increases student engagement in learning activities. The majority of students responded positively to this approach, although some challenges were identified, such as time allocation and adaptation to outdoor learning environments. To optimize the implementation of this method, several strategic steps are required. First, time management should be adjusted to ensure all activities are conducted efficiently without disrupting other academic processes. Second, additional learning resources, such as memory cards or educational applications, can assist students in identifying species encountered during learning. Third, environmental adaptation should be considered by providing more flexible facilities, such as semi-open spaces or alternative indoor activities during unfavorable weather conditions. Moreover, strengthening gamification elements can be an effective strategy to enhance student motivation. More interactive game elements will make students more enthusiastic about participating in learning activities. Finally, continuous evaluation is essential to ensure the effectiveness of this method and to identify aspects that need improvement based on field observations. By implementing these measures, permaculture-based learning can become more structured and aligned with students' needs and field conditions, ultimately achieving optimal sustainable learning outcomes.

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