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Development of a Gamification-Based Program to Support ESD Competency Improvement in Botanical Gardens

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ABSTRACT

The Sustainable Development Goals, particularly Goal 4, have been developed and implemented by various educational institutions around the world. As an agent of development, the stated directly University of Education Indonesia (UPI) has the potential to develop and implement ESD, especially through the use of UPI botanical garden. The purpose of this study is to develop a program and measure its effectiveness in terms of ESD capacity and ecotourism potential. This research is a development study using the ADDIE approach in which 74 teacher candidates participated. Program development was successfully implemented by creating: (1) 5 learning resource posts; (2) Botanical ECO gamification learning flow; (3) 5 practical activities; (4) five games that integrated gamification elements; (5) Botanical ECO-Gamification Guidebook; and (6) Instruments to evaluate program effectiveness in terms of ESD competencies and conceptual mastery. The research results showed that the developed instrument had high validity and reliability, and suitable for use (19 items). The Botanical ECO gamification program was rated in the good category for improving collaboration competency (80,41) and in the good category for self-awareness competency (78,77). The implementation of the Botanical ECO gamification program to develop ESD was rated as very well received by students (85.81). The program was rated as excellent (82,17) or eligible for being one of the ecotourism programs on the UPI campus.

Introduction

Education for Sustainable Development (ESD) is one of the 17 main objectives of the Sustainable Development Goals (SDGs). The specific aim of ESD is to achieve inclusive, fair, quality and lifelong education for everyone (Agirreazkuenaga, 2019). In its application, ESD has several challenges that make it less effective. The first challenge is the lack of understanding and awareness of ESD's importance for educators and students (Laurie *et al*., 2016). Second, ESD is not integrated with the curriculum (Albareda *et al*., 2018). Third, there is little training for teachers or prospective teachers regarding ESD (Evans *et al*., 2016; Laurie *et al*., 2016). Fourth, there is a lack of resources in implementing ESD (Kopnina, 2020). Fifth, there is a lack of collaboration in ESD implementation (Ferguson & Roofe, 2020). Research and development to face challenges needs to be studied, designed and tested by the Agent of Development, in this case higher education institutions or university.

Universities have social responsibilities and moral obligations in realizing sustainable development in the surrounding community. Stated directly University of Education Indonesia (UPI), which focuses on education, has an important role in realizing SDGs number 4 in Indonesia. One of the roles of universities in achieving ESD is by developing ESD/SDGs programs and training (Ferguson & Roofe, 2020). The trend of ESD research by the UPI academic community has begun to increase since 2018 until now. For example, five studies examine ESD-based learning models (Lestari, 2022; Lutfianis, 2020; Nursadiah, 2019; Yulianto, 2022; Zahra, 2022). Four studies examine module development (Budiarti, 2022; Nikmah, 2018; Nurhasanah, 2022; Syafitri, 2022) and four studies examine the implementation of ESD in learning in schools (Indrawan, 2021; Rahayu, 2021; Saragih, 2020; Suwarto, 2021). However, these studies are generally carried out off campus or in schools. UPI as a Green Campus should have the opportunity and potential to develop programs and training regarding ESD on campus, especially in the UPI Botanical Gardens.

The UPI Botanical Garden, one of the facilities on the UPI Bumi Siliwangi campus, is a natural laboratory for students especially majoring in Biology Education. This laboratory also plays a role as a social service, environmental service and academic service. Especially in academic services, a lot of pure Biology research uses this garden, while educational research, especially those related to ESD, is still rarely carried out. On this basis, innovation is needed in the form of programs that can utilize botanical gardens as ESD training and research facility. To ensure program The programs developed must match the characteristics of learning objectives to be more effective, in this case those of Generation Z.

Generation Z was born and has grown up with advances in digital technology. The learning process characteristic of Generation Z is mainly based on the use of technology (Andujar & Medinaz, 2019).This generation prefers the use of technology, such as applications and videos on smartphones, over traditional learning (Szymkowiak *et al*., 2021). However, this generation's digital skills also have weaknesses, especially when it comes to learning. Generation Z students are less motivated and motivated to learn (Saxena & Mishra, 2021), tend to give up when faced with difficult tasks (Seibert, 2021) and require active learning with rich learning experiences (Hernandez *et al*., 2020). To overcome this problem, active learning strategies are needed so that students continue to be motivated in learning. Digital-based active learning incorporating ESD can be deployed as ESD programs and training in university. One type of active learning that can be developed is an ECO-Gamification.

ECO-Gamification is a term that refers to the use of game principles and design to support the formation of sustainable awareness regarding the environment (Souza *et al*., 2020). This program integrates digital technology, environmentally friendly learning and gamification principles such as competition, rewards, feedback provided to students (Herrera *et al*., 2019). This activity takes the form of a game that gives students assignments related to environmental changes such as carbon footprint, pollution or climate changes (Douglas & Brauer,

2021). Through this game, apart from teaching environmental and sustainability concepts, students also train critical thinking, problem-solving and collaboration skills (Brady & Andersen, 2021; Lo & Hew, 2020) The integration of ECO-Gamification with the UPI Botanical Garden is expected to open up the potential for developing ESD research at higher education. In this case, ECO-Gamification can be applied in outdoor environments especially Botanical Garden with active learning strategy or outdoor learning.

Research on outdoor learning shows that it can stimulate increases in students' problem-solving abilities (Saefudin *et al*., 2020) and environmental literacy (Khairani *et al*., 2023). Outdoor Learning is also responded positively by students and can improve field skills both individually and in groups (Permana *et al*., 2020). Field skills can be developed by using field Laboratory Activity Design (LAD) which requires students to observe objects or phenomena directly in the field (Sari Dewi *et al*., 2016). The application of LAD in the field is expected to build new knowledge or strengthen existing knowledge by connecting hands-on with minds-on through practicum activities (Hastika & Supriatno, 2023; Supriatno, 2018; Zidan & Supriatno, 2023). Outdoor practicum activities can be integrated with gamification elements and ESD principles to further improve students' ESD competence.

The aim of this research is to develop a program that is integrated with gamification and supports the concepts, principles, and application of sustainable development practices. This research was also designed to look at the potential of the program as Eco-Tourism that supports sustainable development. This program is designed in such a way as to be an innovative learning strategy in the UPI Botanical Garden called Botanical ECO-Gamification.

Method

This research uses the ADDIE (Analysis, Design, Development, Implementation and Evaluation) approach developed by Branch (2010). Participants in this research were prospective biology teacher students who contracted Biodiversity, conservation and environmental knowledge courses for a total of 74 students in the FPMIPA UPI Biology Education study program. The instrument consists of test questions, questionnaires and practical worksheets (worksheets). The instrument tests about ESD competency in the cognitive domain and mastery of concepts related to Biodiversity material. The questionnaire instrument measures ESD competency in the socio-emotional domain, student responses to the program and the program's potential to become ECO-Tourism. All assessment instruments are given to students via Google Form. Data analysis was carried out with the help of SPSS ver.24 software to test the validity, reliability, distinguishing power and difficulty level of the question items. A questionnaire with a 4-point Likert scale was tested and analyzed descriptively based on the percentage of answers obtained.

Results and Discussion

Analysis Stage

The initial stage is an overall analysis of potential, weaknesses and things that can be developed using preliminary studies. A preliminary study was carried out in the form of case study research which revealed the implementation of outdoor learning in biology learning at the UPI Botanical Gardens. Analysis was carried out on the learning strategies used, learning activities, as well as obstacles and potential that could be developed from the UPI Botanical Garden. Observations, interviews and questionnaires were used to collect data and were assisted by triangulation of data from 2 teachers, 24 students and 2 UPI Botanical Garden managers. The results of the case study reveal that outdoor learning was carried out several times in the UPI botanical garden. However, based on the results of questionnaires and interviews that have been conducted, it is known that the learning strategies used to study in the Botanical Garden are not yet systematic and interesting. Learning resources or collections in the Botanical Gardens are incomplete according to both teachers and students. Students believe that the learning activities carried out are monotonous and

have not been integrated with digital technology. The teacher suggested that the learning strategy should be in the form of active learning and forming groups so that it is easier to organize and students can learn actively. The manager of the UPI Botanical Garden stated that the addition of flora and fauna should support each other to make maintenance easier and continue to be sustainable.

Based on the results of the preliminary study explained previously, there is a need for learning strategies with activities thatare structured and interesting and centered on student activities. Optimizing the botanical garden by adding flora and fauna collections or other learning resources in the UPI Botanical Garden. The added learning resources need to be integrated with technology so that they can be accessed as learning media for students or visitors to the UPI Botanical Gardens. Sustainability concepts and principles are key to developing learning resources. Therefore, the learning resources that will be created are adapted to the concepts and principles of sustainable development goals. Learning these concepts and principles then needs to be packaged into interesting and fun learning strategies so that they are easy to understand and motivate students to learn. It can be concluded that an active learning strategy is needed with learning resources that support the SDGs and are integrated with technology in the UPI Botanical Garden.

Design Stage

The learning strategy is designed based on the findings from the analysis stage or learning case studies in the Botanical Gardens that have been implemented. Researchers also conducted a literature study regarding the ESD competency framework (Scherak & Rieckmann, 2020; UNESCO, 2017, 2018). Based on the results of the literature study, researchers adopted 8 important competencies to develop, including: (1) systems thinking competencies; (2) anticipatory competence; (3) normative competence; (4) critical thinking competence; (5) collaboration competence; (6) self-awareness competency; (7) strategic competence; and (8) problem solving competence. These competencies will be built with practicum activities or LAD carried out in several learning posts. The learning posts designed are examples of sustainable development practices. Design 5 learning resource posts, namely: (1) *Trigona* Bee Cultivation Post; (2) Aquaponic System Post; (3) Oyster Mushroom Cultivation Post; (4) *Black Soldier Fly* (BSF) Maggot Cultivation Post; and (5) Soil Erosion Model Post. Furthermore, researchers designed 5 practical activities, including: (1) measuring the sugar content in honey; (2) testing aquatic factors in aquaponic systems; (3) measuring climatic factors in mushroom cultivation; (4) observing the life cycle of *Hermetia illucens*; and (5) measuring the level of turbidity from the soil erosion model.

An environmental approach and technology approach were used in this program. The learning model that will be used is experiential learning based on Dewey theory (Grady & Role, 2003). The learning method that will be used in this program is in the form of experimental learning. The general learning structure is explained in Table 1. The learning media that will be used is in the form of real objects or models of concepts that can be found in each post. At this stage, researchers also design game elements such as scores, achievements, competitions to be further integrated with learning strategies. The researcher then designed a guidebook for the overall flow of activities called Botanical ECO-Gamification Guidebook. The book consists of (1) a plan of the activity location; (2) terms in activities; (3) overall flow of activities; (4) a brief explanation of the games or games; (5) rewards and achievements; and (6) a brief description of each learning post.

Table 1. Learning Structure of Experiential Learning Model

Stage	Student's Learning Structure	Model Stage	Teacher's Learning Structure
1	Students carry out practical activities with E-LAD guidance at the Learning Post	Real Experience	The teacher guides students to access E-LAD
2	Students link practical activities with the knowledge gained from the QR Code Info in the learning resource post	Reflective Observations	The teacher reminds students about information on learning resource posts from QR Code Info
3	Students build new concepts by linking initial knowledge with practicum results	Conceptualization	Teachers help students build concepts by asking questions related to learning resource posts
4	Students implement new concepts in new situations in questions on E-LAD	Experimentation	The teacher asks students to work on questions from E-LAD

Development Stage

In this stage, there is integration between learning resources, learning strategies and gamification which have been designed to support students' ESD competencies. Gamification in this program takes the form of prerequisite games and the application of game elements such as competition, rewards or achievements, scores and scoreboards that are adjusted to each post. The games played are physical activities carried out as a team by competition. Activities carried out as a team (group) in outdoor learning activities can develop students' skills to plan things together, organize activities, be responsible for the group, build communication and interact with group members (Permana *et al*., 2020). The game elements that are applied can provide a new learning atmosphere that is less monotonous and more fun with challenges that must be completed which will build a positive sense of competition.

Gamification in the form of prerequisite games means that students are required to compete with other groups to get instructions for the next activity. These instructions are in the form of a QR Code that can be scanned and direct students to Google Docs containing practical activities/E-DKL. 5 games were developed for each learning post, including: (1) Chain Hula-hoop; (2) Guess the Word & Hydroponic Making Competition; (3) Mushroom Mini Puzzle & Quest; (4) Botanical Crossword; and (5) Botanical Treasure Hunts. The game is carried out by students called Players who are guided by a teacher called the Game Master. There are two groups competing with each other to see who can quickly find the clue or complete the puzzle to continue the practical activity. Play is limited until a group wins or time runs out (15 minutes). The group that wins the game gets Fast Team (FT) points and can be collected at each post.

The gamification elements developed in this program are competition, points, scores, hidden levels, final levels, and achievements. The competition is held in prerequisite games before practical activities. Points refer to the FT points that must be collected by the group at each post. Score refers to the individual score obtained in the last assessment. Hidden Level refers to a QR Code that is affixed hidden to add to the individual/group total score at the end of the game. Final level refers to the final assessment which contains questions on mastery of concepts or principles found in each post. Students who have the highest score at the final level will receive a certificate in the form of Best Player as an Achievement. The group that collects the most FT points will receive a Best Team certificate as an Achievement at the end of the activity.

Implementation Stage

A week before the activity is carried out, students are given a guidebook. At each learning post, there are requirements that

students must master, such as being able to operate a hand-refractometer. Procedures for using the tools can be found in the QR Code Info which is found in the manual or attached to the post. QR Code Info also contains general information that students need to master regarding learning posts. Students scan the QR Code Info and are then directed to Google Docs which contains information regarding posts and links that lead to *YouTube* regarding tool use.

Learning activities are carried out with an allocation of 2 credits or 100 minutes. The pretest and posttest questions consist of 15 multiple-choice questions to measure mastery of concepts related to biodiversity topics and 10 essay questions to measure ESD competency. The results of the instrument test related to the multiple-choice questions and essay questions are explained in Table 2.

Table 2. Results of Instrument Testing

Test Type	Item No.	R	V	DL	DP	Conclusion
Multiple Choice (Concept Mastery	1	0.73	0,517	74,32	0,55	Eligible
	2		0,402	89,19	0,20	Eligible
	3		0,581	59,46	0,80	Eligible
	4		0,136	64,86	0,15	Discarded
	5		0,082	10,81	0,10	Discarded
	6		0,373	63,51	0,45	Corrected
	7		0,309	86,49	0,35	Corrected
	8		0,558	77,03	0,55	Eligible
	9		0,485	54,05	0,55	Eligible
	10		0,477	75,68	0,50	Eligible
	11		0,657	47,30	0,80	Eligible
	12		0,229	90,54	0,20	Eligible
	13		0,539	71,62	0,65	Eligible
	14		0,346	67,67	0,40	Eligible
	15		0,290	81,08	0,25	Eligible
Essay (Cognitive Domain of ESD Competencies)	1	0.87	0,794	83,93	0,27	Eligible
	2		0,585	46,43	0,24	Eligible
	3		0,672	67,86	0,29	Eligible
	4		0,809	58,93	0,35	Eligible
	5		0,559	61,90	0,17	Eligible
	6		0,607	55,36	0,25	Eligible
	7		0,379	61,90	0,07	Corrected
	8		0,691	64,88	0,30	Eligible
	9		0,767	64,29	0,31	Eligible
	10		0,612	69,64	0,11	Eligible

R = Reliability; V = Validity; DL = Difficulty Level; DP = Differentiating Power

Based on Table 2, it is known that multiple choice questions have a reliability value of 0.73 which is categorized as high. Based on validity measurements, level of difficulty and differentiating power, it was found that from the 15 questions, there were 10 questions that were suitable for use, 3 questions that needed to be corrected and 2 questions that were discarded. The multiple-choice questions are then used as pretest and posttest questions to measure mastery of concepts on the topic being measured, in this case the topic of biodiversity. Furthermore, it was found that the reliability of the essay questions developed had a value of 0.87 or was categorized as very high. The majority of questions or 6 questions have a high level of validity, one question has very high validity, two questions have medium validity and one question has low validity. We concluded that 9 questions were used or eligible in the research and 1 question was corrected. In

general, it can be said that the essay questions used to measure ESD competency are suitable for use by improving one question.

Responses from students regarding the implementation of the Botanical ECO-Gamification program were collected through a response questionnaire given after learning. The questionnaire statement consists of responses to the suitability of the material, ESD competency, as well as the presentation of the Botanical ECO-Gamification program. Student responses are an important indicator for measuring student satisfaction with the learning experience through the Botanical ECO-Gamification program. This data is also one of the keys to evaluating the success of the program and is a consideration for developing this program further. The results of data analysis show that the average value of student responses is in the very good category (85.81). This indicates that the Botanical ECO-Gamification program was well received by students in its implementation. The response values for each aspect can be seen in Figure 1.

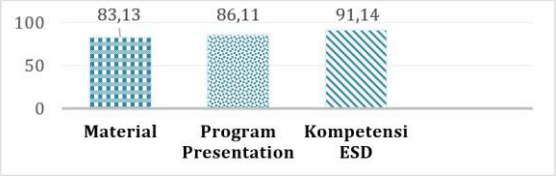

Figure 1. Percentage of Student Responses to the Implementation of the Botanical ECO-Gamification Program

Based on Figure 1, it was found that the highest percentage of responses was in ESD competency (91.14) in the very good category. The ESD competency in question is a sustainability competency contained in every learning activity through the Botanical ECO-Gamification program. Student responses regarding ESD competencies such as building the ability to collaborate with fellow team members in completing missions and challenges. Then, with learning resources that have been adapted to sustainability practices, students can directly understand the principles of sustainability. Implementation of the Botanical ECO-Gamification program in botanical gardens also provides an ideal environment for improving sustainability competencies. This is supported by direct experience of the natural environment, so that students can develop awareness of the importance of protecting and preserving the environment (Lismaya, 2018; Mufid *et al*., 2022).

Student responses to aspects of the program presentation received a percentage of 86.11% in the very good category. Students stated that the program provided was a new, motivating learning experience that had never been done before. Then this program also helps students collaborate with other friends through the missions and challenges given. Integrating technology in the form of a QR Code in every activity also makes it easier for students to participate in learning. The presentation of the Botanical ECO-Gamification program follows the principles of active learning, by combining environmental and gamification approaches as well as integrating technology. This is intended as an innovation in learning strategies using ECO-Gamification principles in Botanical Gardens. According to Souza *et al*., (2020), ECO-Gamification provides a learning by doing experience in a fun way in the form of ECO-friendly activities. Presenting the program outdoors also makes it possible to develop social skills, where students can learn to collaborate, communicate and work together well to connect learning with real life (Mahyatun *et al*., 2020; Wahyuni *et al*., 2017)

Student responses to the suitability of the material obtained a percentage of 83.13% in the good category, which means that the Botanical ECO-Gamification program supports good mastery of the concept of the material raised, namely Biodiversity material. Students responded that this program helped them learn the material in a way that was fun, interesting to learn, closely related to daily life and compatible with learning resources in the botanical garden. Through outdoor experiences, students can see how the concepts and theories learned can be applied in real situations in society or nature (Groff *et al*., 2005; Nedovic & Morrissey, 2013)

The development of the Botanical ECO-Gamification program in botanical

gardens is considered to have potential as ECO-Tourism for University. The potential of ECO-Tourism is measured using a tourist attraction potential questionnaire which refers to four main components, namely attraction, amenities, accessibility and ancillary service. These four components can be indicators of the tourism potential of the Botanical ECO-Gamification program on the UPI campus, specifically in the Botanical Gardens. Tourist visits can later be used as Income Generating Units (IGU) which can be used by universities to fund the development of ESD research, renovation and additions to Botanical Garden collections, as well as development of the Botanical ECO-Gamification program. The results of the questionnaire analysis of the ECO-Tourism potential of the Botanical ECO-Gamification Program can be seen in Table 3.

Table 3. Analysis of the Program's Potential to Become ECO-Tourism

Overall Indicator	Measured Factor	Value	Interpretation
Program Potential as ECO-Tourism	Maximum Value	92,46	Very Well
	Minimum Value	71,83	Sufficient
	Averages	82,17	Well

Based on the results of the questionnaire analysis in Table 4, it can be seen that the tourism potential or ECO-Tourism Botanical ECO-Gamification Program is in the good category (82.17). This indicates that this program can be a good tourism potential for the UPI campus as a Green Campus. The first aspect that is an indicator is that the attraction or attractiveness of an area is used as a tourist attraction (Harianto *et al*., 2021) Indicators of this aspect include the natural beauty of the botanical garden, the clean environmental conditions of the botanical garden, a diverse and interesting plant collection, as well as photo spots that support tourists in capturing tourist moments. The first aspect, botanical gardens through the Botanical ECO-Gamification program have attractions or tourist attractions in the form of natural resources and artificial attractions in the form of games or games. This is in line with the statement (Harianto *et al*., 2021) which explains that the attractions or attractiveness of tourist objects are divided into three, namely natural resources, cultural tourism, and artificial attractions such as sports events, games, exhibitions, etc. The biodiversity found in the botanical garden area makes this place suitable for educational tourism with interesting photo spots for visiting tourists.

Conclusion

This development research produced a program plan in the form of (1) 5 learning resource; (2) Botanical ECO-Gamification learning flow; (3) 5 practicum activities summarized in E-LAD; (4) 5 fun games that integrate gamification elements; (5) Botanical ECO-Gamification guidebook; and (6) an instrument for assessing the effectiveness of the Botanical ECO-Gamification program on ESD competency and concept mastery. Instrument testing results showed that the developed instrument had high validity and reliability, and was suitable for use (19 items). Furthermore, the results show that the Botanical ECO-Gamification program was responded to by students with an average of in the good category (80.41) to increase collaboration competence in ESD. Student responses to the program were also categorized as good (78.77) for increasing self-awareness competence in ESD. The implementation of the Botanical ECO-Gamification program to develop ESD was generally responded very well (85.81) by students based on the results of the response questionnaire. The program was rated as good (82.17) by the average student to become one of the ECO-Tourism on the UPI campus. The Botanical ECO-Gamification program can be an alternative program for introducing and teaching ESD competencies for students and prospective teachers. The program implemented can be integrated into courses that focus on concepts and theories of sustainable development at tertiary level. However, program activities need to be adapted to the curriculum at the relevant school so that it suits the cognitive level of students and the expected learning

outcomes. Further research is needed to see the effectiveness of the program when implemented at lower levels.

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