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The Effect of Digital Game-Based Learning on Students' Problem-Solving Skills in The Context of Sustainable Organic Farming

Emilia Candrawati[1*], Silvia Syeptiani[1], Arsela Eko Listiono[1]

[1]Natural Science Education Department, Faculty of Teacher Training and Education, Universitas Bengkulu, Indonesia

*Corresponding author's email: emiliacandrawati@unib.ac.id

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Abstract

This study aims to implement the Digital Game-Based Learning (DGBL) model through the EcoFarm Challenge educational game to improve students' problem-solving skills. This research uses a research and development (R&D) approach combined with a quasi-experimental design and a one-group pretest-posttest design involving 18 students. Data analysis was performed using the Shapiro–Wilk normality test and the Wilcoxon Signed-Rank Test. The results showed that the data were not normally distributed ($p < 0.05$), so the Wilcoxon test was used. The test results showed a significant difference between the pretest and posttest ($Z = -2.312$; $p = 0.021$) with a large effect size ($r = -0.788$). Data visualization using a raincloud plot also showed an upward trend in scores despite individual variation. These results indicate that the DGBL model is effective in improving students' problem-solving skills through interactive, simulation-based learning experiences.

Keywords: digital game-based learning, problem-solving, local plant cultivation, organic farming, innovative learning

INTRODUCTION

Higher education is increasingly expected to not only impart theoretical knowledge but also to develop higher-order thinking skills, particularly problem-solving skills, which are essential for addressing complex scientific problems (OECD, 2021). In science education, including fields related to chemistry, problem-solving skills involve the ability to analyze phenomena, interpret data, and make decisions based on scientific reasoning. This competency is crucial for prospective science teachers, as they are expected to facilitate meaningful learning and guide students in understanding real-world scientific problems.

In the Science Education Study Program at one of the universities in Bengkulu, the Local Plant Cultivation course has strategic potential for developing these competencies, particularly in the context of applied science and chemistry. The course's content is closely linked to chemical concepts such as soil chemistry, nutrient cycling, organic and inorganic fertilizers, and environmental chemical processes that affect plant growth. Therefore, this course provides an authentic context for developing students' problem-solving skills through the application of chemical concepts in real-life situations.

However, based on learning observations and internal evaluations conducted in 2024, students still demonstrated low ability to solve case-based problems and apply scientific concepts to real-world situations. Learning activities were generally limited to descriptive exploration of plants and simple cultivation practices, without engaging students in analytical processes and decision-making. Furthermore, learning approaches have not optimally utilized interactive digital media that align with the characteristics of digital-native learners. As a result, students tend to have shallow conceptual understanding and limited ability to apply knowledge in problem-solving contexts.

To address this issue, innovative learning approaches are needed that can actively engage students in meaningful learning experiences. One promising approach is Digital Game-Based Learning (DGBL), which integrates learning content with game elements to create an interactive and immersive learning environment. DGBL has been shown to increase engagement, motivation, and higher-order thinking skills by providing simulation-based experiences that require students to make decisions and solve problems (Plass et al., 2020; Tokac, 2019). In science education, DGBL can facilitate the understanding of abstract concepts through contextual and interactive representations.

Recent studies have highlighted that DGBL is particularly effective when it incorporates complex problem scenarios and decision-making processes. For example, research by Azis et al. (2025) demonstrated that game-based learning environments significantly improve students' problem-solving skills by provides a platform for students to experience real-world problem-solving scenarios in an interactive and collaborative environment. Similarly, Kraska et al. (2020) found that digital simulation games support deeper conceptual understanding and encourage analytical thinking. These findings suggest that DGBL is not only a motivational tool but also an effective pedagogical approach for developing cognitive skills.

However, most existing DGBL implementations remain generic and rarely integrate domain-specific and contextual content, particularly those related to chemistry-based applications in local contexts. This represents a significant research gap, particularly in the Indonesian higher education context, where learning is expected to be relevant to local potential while leveraging digital technology. Integrating chemistry concepts into a locally contextualized DGBL environment can provide a more meaningful learning experience and strengthen students' ability to apply scientific knowledge to solve real-world problems.

In the Bengkulu context, local crop cultivation practices provide a rich context for applying chemistry concepts such as soil fertility, nutrient management, and the impact of chemical inputs on plant growth. However, this potential has not been optimally developed through interactive, technology-based learning media. Therefore, this study proposes the implementation of the DGBL model through the EcoFarm Challenge game, designed to engage students in a problem-solving process involving analysis, solution selection, decision-making, and evaluation in simulated real-world scenarios.

Through this approach, students are expected to not only understand the concepts but also develop problem-solving skills through active engagement in a dynamic learning environment. This aligns with constructivist learning theory, which emphasizes that knowledge is built through experience and interaction (Huang et al., 2022). Therefore, the integration of DGBL into the Local Plant Cultivation course is expected to provide an effective strategy for enhancing students' problem-solving skills in science learning.

METHOD

This research uses a research and development (R & D) approach combined with a quasi-experimental design. The development of the learning model and media was carried out based on the ADDIE model proposed by Robert M. Branch (Branch, 2009), which includes five main stages, namely analysis, design, development, implementation, and evaluation. The analysis stage identified learning needs and analyzed student problems in the Local Plant Cultivation course. The design and development stage included the design and creation of the EcoFarm Challenge educational game. The game was validated by experts as part of a formative evaluation to ensure the product's feasibility before implementation. After the product was declared feasible, the implementation stage was carried out by applying the DGBL model to classroom learning. To test the effectiveness of the developed model, this study used a one-group pretest-posttest quasi-experimental design (Creswell, 2012). The design was chosen based on the limited classroom control and the research objectives, which included not only developing a learning product but also examining the impact of its implementation on improving student skills. Thus, the design allowed researchers to directly compare changes in student abilities following the implementation of the DGBL model.

The participants in this study were 18 fifth-semester students of the Science Education Study Program at a university in Bengkulu. Participants were selected using a purposive sampling technique, considering that students had taken a relevant course, but hadn't yet taken a course on local plant cultivation. All participants participated in learning activities using the DGBL model and took pre- and post-tests as part of the research data collection.

This research was conducted in accordance with the ethical principles of educational research. All participants were provided with an explanation of the research objectives, implementation procedure, and expected benefits prior to the study. Student participation was voluntary and based on informed consent. Confidentiality of participant data was maintained by not including personal identification in the research report, and all data collected was used solely for academic purposes.

The research instrument consisted of a problem-solving skills test. The problem-solving skills test was structured in multiple-choice format, addressing indicators of problem-solving ability, such as the ability to identify and analyze problems, analyze solutions, implement the solutions, and evaluate. The problem-solving skills test outline is presented in Table 1.

Table 1. The Problem-Solving Skills Test outline

Indicator	Cognitive Level	Number Question Item
Problem identification	C2 (understanding)	1,2
Problem analysis	C4 (Analyzing)	3, 4
Solution selection	C4 (Analyzing)	5, 6
Solution implementation	C6 (Creating)	7, 8
Evaluation	C5 (Evaluating)	9, 10

Data analysis was conducted using descriptive and inferential statistics. Normality was tested using the Shapiro-Wilk test to determine data distribution. Because the data were non normally distributed ($p < 0.05$), the analysis of the differences between pretest and posttest scores was continued using the non-parametric Wilcoxon Signed-Rank Test. All data analyzis was performed using JASP Statistical Software.

RESULT AND DISCUSSION

Characteristic of DGBL Model for Local Crop Cultivation Courses on Organic Farming and Environmental Impact

The results of this study indicate that the Digital Game-based Learning (DGBL) model, implemented through an educational game titled EcoFarm Challenge, possesses characteristics that function not only as a learning medium but also as an experiential learning environment. This model is designed by integrating instructional design principles and game mechanics, enabling students to construct knowledge through direct interaction with contextual problems.

One of the main characteristics of DGBL in this study is based on contextual problem-based learning. The problems presented in the game relate to environmental degradation caused by non-organic farming practices, which is a real-world issue in society. This approach aligns with recent research findings indicating that contextual teaching and learning combined with game-based learning can encourage students to be active and directly involved in learning, while emphasizing experience, thereby enhancing conceptual understanding (Pebrianti et al., 2023).

Furthermore, the DGBL developed features with interactive and decision-based learning characteristics. Students don't merely receive information but actively determine strategies to solve problems presented at each game level. This activity fosters higher engagement, particularly in the areas of analysis and evaluation. Research by Ahmat et al. (2021) indicates that decision-making tasks in digital games significantly contribute to the development of higher-order thinking skills, including problem-solving skills.

These characteristics are visually and functionally reflected in the interface design of the EcoFarm Challenge Game. The game interface is designed to represent an experience-based learning pathway through several main, interconnected stages. The interface is shown in Figure 1.

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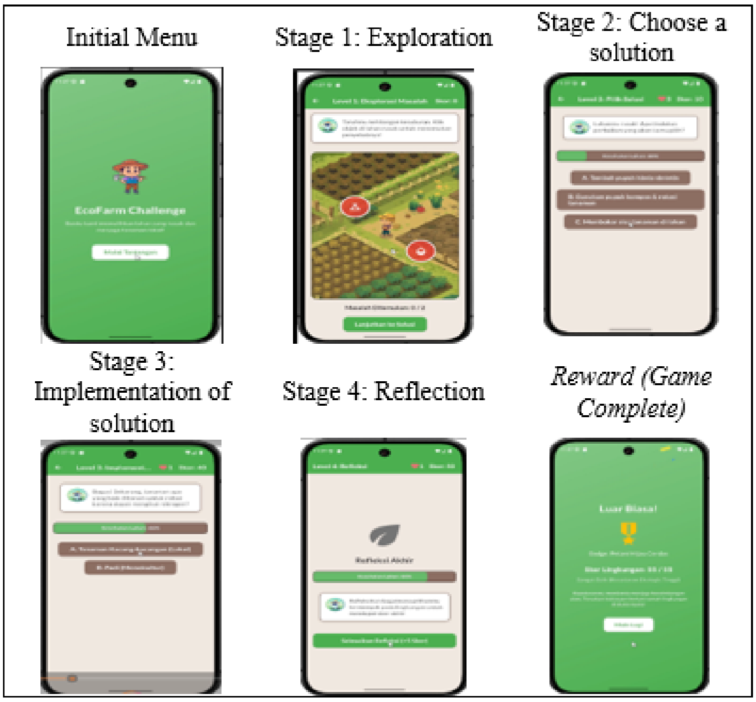

Figure 1. User interface of *game-based simulation* "EcoFarm Challenge"

The EcoFarm Challenge game is designed with a duration of 10-15 minutes per session, featuring four game levels that are aligned with the learning stages and problem-solving skill indicators. The first level focuses on exploring damaged land conditions and introducing problems, the second level on selecting conservative solutions based on organic farming principles, the third level on implementing solutions based on local plants and organic fertilizers, and the fourth level on reflecting on the results of decisions made through a visual feedback system, environmental scores, and digital badge rewards. The game system combines interactive exploration mechanics with dynamic feedback so that students are actively involved in deciding and evaluating the ecological impact of their actions.

In addition to being evident in the game interface, the characteristics of DGBL in this study are also operationally incorporated into the learning syntax of the Course Activity Plan (SAP), which is systematically designed to last 100 minutes. Thus, syntax includes (a) exploration, (2) engagement and challenge, (3) engagement and implementation, and (4) reflection and reward.

In the exploration stage, students are introduced to the problem context through an initial simulation within the game. The engagement and challenge stage facilitates students' active involvement in identifying problems and determining alternative solutions. Next, in the engagement and implementation stage, students implement the chosen decision within the game scenario. The reflection and reward stage provides students with the opportunity to reflect on the outcomes of their decisions, while also receiving feedback. Thus, this syntax not only represents the DGBL workflow but also reflects a structured learning process oriented toward the development of problem-solving skills.

Therefore, the characteristics of DGBL developed in this study reflect a combination of pedagogical, technological, and local contextual aspects that are systematically integrated into learning syntax. The synergy of these three aspects has proven capable of creating learning that is more meaningful, interactive, and relevant to students' needs in the digital age.

The Effectiveness of the DGBL Model in Local Crop Cultivation Courses in the Context of Organic Farming on Problem-Solving Skills

Before conducting a difference test, a normality test was first performed using the Shapiro–Wilk test to ensure the selection of an appropriate analytical technique. The test results showed that the pretest and posttest data were not normally distributed ($p = 0.001$), so the analysis proceeded using a nonparametric test, namely the Wilcoxon Signed-Rank Test. The analysis results indicated a significant difference between students' pretest and posttest scores after implementing the DGBL model. This is indicated by a Z statistic value of -2.312 with a significance value of $p = 0.021$ ($p < 0.05$). The complete Wilcoxon Signed-Rank Test results are presented in Table 2. Thus, it can be concluded that implementing the Digital Game-Based Learning (DGBL) model through the EcoFarm Challenge game significantly improved students' problem-solving abilities.

Table 2. The Wilcoxon Signed-Rank Test Result

<table>
<tr><th rowspan="2">Measure 1</th><th rowspan="2">Measure 2</th><th rowspan="2">Test</th><th rowspan="2">Statistic</th><th rowspan="2">z</th><th rowspan="2">df</th><th rowspan="2">p</th><th rowspan="2">Effect Size</th><th rowspan="2">SE</th><th colspan="2">95% CI for Effect Size</th></tr>
<tr><th>Lower</th><th>Upper</th></tr>
<tr><td rowspan="2">Pre</td><td rowspan="2">Post</td><td>Student</td><td>-2.650</td><td></td><td rowspan="2">17</td><td>.017</td><td>0.625</td><td>0.412</td><td>-1.124</td><td>-0.110</td></tr>
<tr><td>Wilcoxon</td><td>7.000</td><td>-2.312</td><td>.021</td><td>0.788</td><td>0.328</td><td>-0.940</td><td>-0.378</td></tr>
</table>

In addition to statistical significance, the effect size also showed strong results, at $r = 0.788$, which is included in the large effect size category based on Pearson’s Correlation Guidelines (Brydges, 2019). This indicates that the improvements were not only statistically significant but also had a significant practical impact on students' problem-solving abilities. This finding is also supported by the visualization of the distribution of pretest and posttest scores shown in Figure 2.

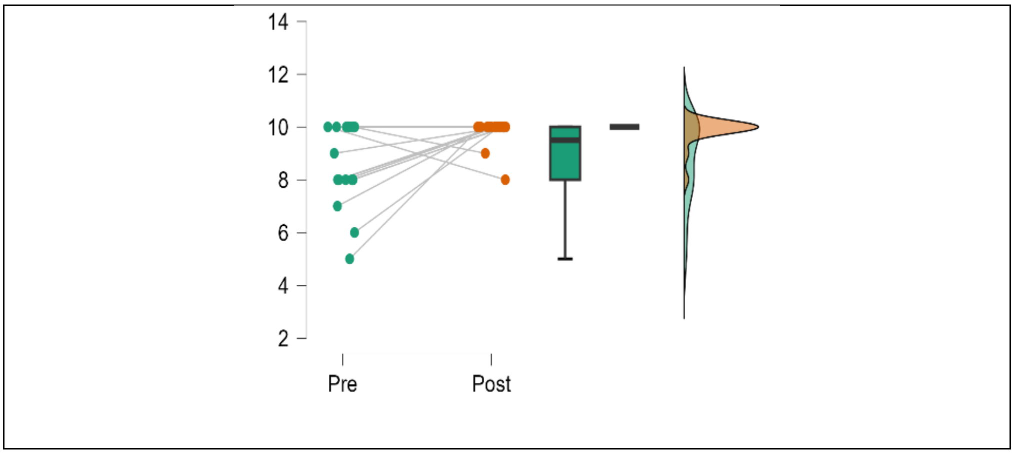

Figure 2. Visualization of the distribution of pretest and posttest scores on students' problem-solving skills using a raincloud plot

The graph shows that most students experienced an increase in their scores, as evidenced by the line connecting the points, which tends to increase from pretest to posttest. This indicates that the majority of participants experienced improvements in their problem-solving abilities after participating in DGBL-based learning.

However, some students showed a decrease in their scores after the intervention. This variation indicates differences in individual responses to DGBL implementation, which can be influenced by factors such as initial ability, level of adaptation to digital media, and engagement during the learning process (All et al., 2016). Nevertheless, the overall distribution of scores still shows an upward trend, as evidenced by the higher median position of the posttest compared to the pretest and the concentration of scores in the high score range (around 9–10). Furthermore, the distribution of scores on the posttest tended to be more homogeneous, indicating that most students achieved a more even level of understanding after the treatment.

The presence of some decreases in scores did not alter the main conclusion of the study, as the Wilcoxon test results still showed significant differences. In nonparametric analysis, the primary focus is on the overall trend in the data, not on individual changes alone. Therefore, overall, the DGBL model remained effective in improving students' problem-solving skills.

Substantively, this improvement in problem-solving skills can be explained by the characteristics of DGBL learning, which positions students as active problem solvers in an interactive and contextual learning environment. In the EcoFarm Challenge game, students are faced with complex situations that simulate real-life problems related to environmental degradation due to unsustainable agricultural practices. Through these scenarios, students actively engage in the process of identifying problems, analyzing alternative solutions, making decisions based on ecological considerations, and evaluating the impact of their decisions.

This process directly trains the main components of problem-solving skills: analysis, synthesis, and evaluation. Game-based learning environments that simulate complex problems are effective in improving problem-solving skills because they provide a learning experience that closely approximates real-world conditions (Clark et al., 2016). Furthermore, the use of simulations in DGBL allows students to explore and engage in trial and error without real-world risks, thus encouraging deeper learning (Hwang et al., 2014).

The effectiveness of DGBL in this study was also influenced by the immersive learning experience, where students are not only cognitively but also emotionally engaged in the learning process (Zheng et al., 2024). This engagement increases intrinsic motivation and creates a state of flow, which contributes to increased knowledge retention and skill transfer to new situations (Bai et al., 2020). Thus, learning becomes more meaningful compared to conventional approaches, which tend to be passive.

CONCLUSION

This study successfully designed and developed a Digital Game-Based Learning (DGBL) model integrated with the context of organic farming and environmental impacts in the Local Plant Cultivation course. The EcoFarm Challenge educational game prototype has been functionally tested and successfully improved students' problem-solving skills. The Course Activity Plan (SAP) design supporting the implementation of the DGBL model has been systematically developed and is relevant to the needs of science learning. Data analysis results indicate a significant improvement in students' problem-solving abilities after the DGBL model was implemented.

For further development, it is recommended that the EcoFarm Challenge game prototype be equipped with a wider variety of local environmental cases to train students in solving contextual problems. The DGBL model should be implemented with a larger number of students to obtain more representative empirical data. The integration of Bengkulu's local wisdom values needs to be continuously strengthened in the game narrative to familiarize students with the biological and social potential of their region. The results of this study can serve as a basis for developing similar DGBL models in other courses in science and environmental conservation. Therefore, the developed DGBL can be a real innovation in transforming science learning based on technology and local potential at the University of Bengkulu.

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