Journal of Innovation in Educational and Cultural Research

Volume 3 Issue 4 Year 2022 Pages 691-700
ISSN 2722-9688 | e-ISSN 2722-9696
http://jiecr.org | DOI: 10.46843/jiecr.v3i4.344

The Effect of Environmental Pollution Game-Based Learning on Improving Students' Conceptual Understanding and Environmental Awareness

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Abstract: The purpose of this study is to analyze the effect of "Environmental Pollution Game-Based Learning (EPGBL)" on improving students' conceptual understanding and environmental awareness. EPGBL is an android-based learning media that can be used in science learning, particularly for environmental pollution concepts. Quasi-experimental research with pretest and posttest group design was utilized to answer the research questions in this study. The average percentage of correct responses in the pre-test is 61.33, meanwhile, the percentage of correct responses in the post-test is 73.33. This result showed that the percentage of correct responses in the post-test is higher than in the pre-test. The results showed that EPGBL can improve students' conceptual understanding of environmental pollution concept. The average score of the students' environmental awareness character is 3.98 that include in the good criteria. In conclusion, EPGBL is effective in improving students' conceptual understanding and environmental awareness.

Keywords: conceptual understanding; environmental awareness; environmental pollution; game-based learning

Recommended citation: Widyatmoko, A., Taufiq, M., Purwinarko, A., Wusqo, I. U., & Darmawan, M. S. (2022). The Effect of Environmental Pollution Game-Based Learning on Improving Students' Conceptual Understanding and Environmental Awareness. *Journal of Innovation in Educational and Cultural Research*, *3*(4), 691-700.

INTRODUCTION

Technological developments are very rapid in this 21st century (Vargo et al., 2021). Industrial revolution 4.0 requires digital technology, including digital mobile phone technology (Afandi et al., 2019; Malik, 2018). During the current COVID-19 pandemic, the use of mobile phones dominates the education sector (Almendingen et al., 2021; Islam et al., 2020). This is because schools are conducted online, which aims to prevent the spread of the COVID-19 virus. Students feel bored in undergoing online learning because the teacher only gives assignments that must be done by students (Subekti, 2021). Despite this situation, learning must continue to run well. Learning innovation is a solution that needs to be developed, designed, and implemented by teachers. One of them is optimizing learning media through mobile phones (Almendingen et al., 2021).

A mobile phone is a communication tool that is often used by the public by 69,6% (Mangan et al., 2018). Most junior high school students in the Z generation already own or use Android smartphones. Internet access activities from this smartphone are part of their daily lives (Sari et al., 2019). Through this android smartphone, teachers can innovate by creating interesting learning media in the form of applications. Applications on smartphones that are usually favored by children are games (Brito & Dias, 2020; Yadav et al., 2020). The creation of application innovations in learning media is better directed at GBL (Game-Based Learning) applications (Krouska et al., 2022). To deal with it, innovations in the teaching and learning process are should follow research trends related to gamification.

Several previous studies revealed that the use of GBL had a positive influence on student learning in the classroom. Winatha and Setiawan (2020) showed that student learning achievement increased significantly because of applying game-based learning. Dewantara et al. (2020) found that the use of the "Game Scramble Circuit" can increase student learning motivation which has an impact on improving student learning outcomes. Mao et al. (2022) showed that GBL had a large, significant positive effect on students' critical thinking. Elnovreny (2021) also showed that student gain an understanding of learning applications that are relevant and appropriate for teaching generation Z today, hence increasing instructors' motivation and awareness in creating and developing outstanding and modern learning media. One of the subjects at the junior high school level that can apply to GBL is science.

Science subjects for junior high schools teach the concept of environmental pollution. Environmental pollution is a very contextual material faced in the daily life of students (Ichsan et al., 2019). Cases of water, air, and soil pollution can almost always be found in the environment around students, so this material is

important to be raised as material for the development of DGBL (Digital game-based learning). DGBL needs to be applied to the concept of environmental pollution because the material content can be combined with animation, visualization, simulation, and educational games that can increase students' interest in learning (Hao, 2021). DGBL can visualize the concept of environmental pollution to be more real so that students can easily understand and don't feel bored because this DGBL also contains educational games. This environmental pollution is related to students' environmental awareness.

Environmental awareness among students is still low at this time (Ramadhan et al., 2019). This is very worrying because students are future generations who must be able to maintain the environment (Ramadhan et al., 2019). Several previous studies have conducted research on students' concept understanding and environmental awareness, they are Naezak et al. (2021) which developed the guided inquiry learning model assisted by a simple terrarium. The result was the guided inquiry learning model assisted by a simple terrarium is feasible to improve students' conceptual understanding and environmental virtue ethics. Sagala et al. (2019) in their research conclude that there are differences in STEM and conventional learning on concepts understanding and the use of STEM learning is more effective than the conventional one. Nowadays, one of the methods that can be used to overcome these problems is to use learning tools oriented Industrial Revolution 4.0.

Students' role in promoting environmental sustainability is very important (Rahman, 2020). Yeşilyurt et al. (2020) said that students who received environmental education, draw pictures enthusiastically and reflecting environmental awareness. It can also support the SDGs 2030 goals on the environment. Caring for the environment is a character that needs to be developed in every subject at the education level, this is a form of preserving the natural surroundings. Developing and strengthening the interest in environmental activity are one of the most important educational tasks (Nazarenko & Kolesnik, 2018). The research objective in this research is analyze the effect of using EPGBL (Environmental Pollution Game-Based Learning) on students' conceptual understanding and environmental awareness. EPGBL is expected to be effective in increasing students' understanding of environmental concepts and concerns on environmental pollution material.

METHODS

Research Design

This study aims to analyze the effect of using EPGBL (Environmental Pollution Game-Based Learning) on students' conceptual understanding and environmental awareness. Quasi-experimental research (Rogers & Revesz, 2019) with pretest and posttest design was used to conduct this study. The sample of this study consisted of 20 junior high school student's 8th grade from one of the public schools in Semarang city, Central Java Province, Indonesia. The research was conducted online through Google Meet. The research procedure is presented in Figure 1.

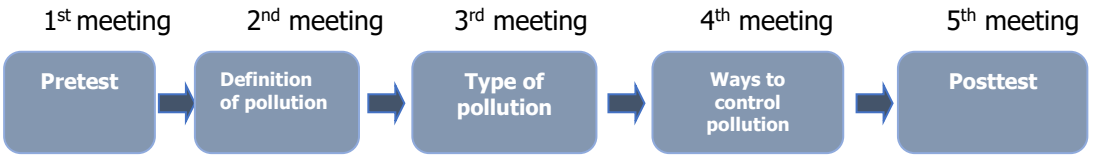

Figure 1. Research Procedure

Research Instruments

The concept taught in this study is environmental pollution. The instruments used in this research are (1) EPGBL (Environmental Pollution Game-Based Learning); (2) Two-Tier Multiple-Choice Tests (TTMCT), and (3) environmental awareness questionnaire.

EPGBL (Environmental Pollution Game-Based Learning)

EPGBL is an android game-based learning media that can be used on environmental pollution concepts. This material is found in Basic Competencies 3.8 Analyzing the occurrence of environmental pollution and its impact on ecosystems and 4.8 Writing about ideas for solving problems of pollution in the environment based on observations. To open the EPGBL, users simply need to download and install the application. The start page of the application is a display of several menus: (1) start, (2) settings, (3) material, and (4) exit. The menu in EPGBL is shown in Figure 2.

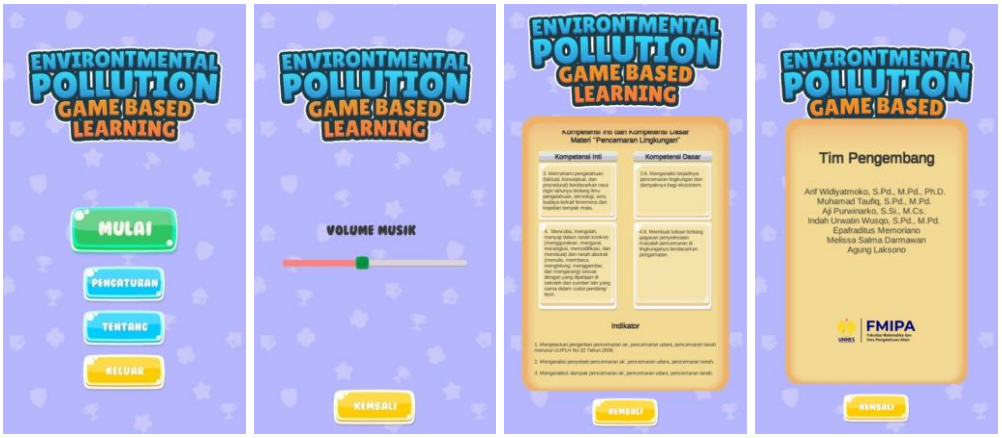

Figure 2. Menu in EPGBL

Two-Tier Multiple-Choice Tests (TTMCT)

The TTMCT (Two-Tier-Multiple-Choice Test) was used in this study to measure students' conceptual understanding of environmental pollution concepts. The TTMCT consisted of twenty items and was administered as pre-test and post-test. The questions used in TTMCT consist of two levels of questions, the first tier is the content of the main question and the second tier is the reason for the answer given based on the first tier (Rintayati et al., 2021). The example of questions in the TTMCT is shown in Figure 3.

1. Excess CO in the air can cause... a. Ozone hole b. Shortness of breath c. Global warming d. Acid rain Reason: a. CO is easily bound by haemoglobin in red blood cells b. CO destabilizes gases in the atmosphere c. CO when reacts with nitrogen can form pollutant with high acid d. CO cannot be degraded	The type of agricultural waste that will be able to cause pollution in an environment is called... a. Pesticides b. Detergent c. Trash d. Residual fertilizer Reason: a. Reduce soil fertility b. Killing organisms c. Dry soil d. Land cannot be cultivated

Figure 3. Example of questions in TTMCT dealing with environmental pollution concept

Environmental Awareness Questionnaire

The environmental Awareness Questionnaire is used to determine the level of environmental awareness of students. Environmental awareness means not only having knowledge about the environment but also relating it to a series of attitudes, behaviors, and a willingness to act to overcome problems related to the environment (Susilawati et al., 2021). There are 35 questions related to 6 dimensions of environmental awareness. Indicators of environmental awareness are presented in Table 1.

Table 1. Indicators of Environmental Awareness

Indicator	Sub Indicator	Question Number
Energy conservation	Behavior can be seen in energy efficiency and savings, as well as starting to switch to renewable energy.	1, 2, 3, 4, 5, 6
Transportation and mobility	Behavior is related to the choice of transportation for daily mobility, to reduce the impact of pollution and reduce fuel consumption.	7, 8, 9, 10, 11
Waste avoidance	Behavior is related to reducing the use of goods that can produce waste and using old goods for reuse.	12, 13, 14, 15, 16, 17
Consumerism	Behavior that is related to shopping for food for consumption, both pro-environmental food.	18, 19, 20, 21, 22, 23
Recycling	The behavior of using goods that are not used into other useful goods.	24, 25, 26, 27, 28, 29
Vicarious, social behaviors toward conservation	Behavior is carried out by playing an active role in managing the environment in a community and increasing awareness.	30, 31, 32, 33, 34, 35

Conceptual Understanding

The test score of students' conceptual understanding was analyzed quantitatively. For each of the TTMCT items, the first tier consisted of one correct answer, and the second tier involved selecting the best reason for the response in the first tier. Students' responses were analyzed to define their understanding. For this purpose, correct answers were converted to percentages. TTMCT items were analyzed with the criteria presented in Table 2.

Table 2. Criteria for analyzing the two-tier multiple-choice test

First tier	Second Tier	Abbreviations	Score
Correct Answer	Correct Reason	CC	2
Wrong Answer	Correct Reason	WC	1
Correct Answer	Blank	CB	1
Correct Answer	Wrong Reason	CW	1
Wrong Answer	Blank	WB	0
Wrong Answer	Wrong Reason	WW	0
Blank	Blank	BB	0

Environmental Awareness

The interval average scores of environmental awareness were analyzed with the criteria in Table 3.

Table 3. Interval average score of Environmental Awareness

Interval average score	Criteria
$4.00 < \text{average score} \leq 5.00$	Very Good
$3.00 < \text{average score} \leq 4.00$	Good
$2.00 < \text{average score} \leq 3.00$	Poor
$1.00 < \text{average score} \leq 2.00$	Very poor

RESULT AND DISCUSSION

Students' Conceptual Understanding of Environmental Pollution Concept

Education in schools can provide students with an awareness of the importance of the value of caring for the environment for life. Pre-test and post-test quantitative data were collected to evaluate students' conceptual understanding using TTMCT. Assessment of higher order thinking skills (HOTS) provides opportunities for students to develop deeper knowledge, serves students' abilities to identify, and solve complex problems, one type of instrument to measure HOTS objectively is TTMCT (Rintayati et al., 2021). TTMCT was given to the experimental group, once at the first meeting before the instruction and once again at the last meeting after completing the instructional learning using EPGBL. In the experimental class, the students' pre-test and post-test results for first-tier and combined-tier for each of the 20 items were analyzed, and the percentages of correct responses to the items were tabulated in Table 4.

Table 4. Percentage of pre-test and post-test answers for first-tier and combined-tier in the TTMCT

Questions	Experimental group			
	Pre-test (%)		Post-test (%)	
	First tier	Combined tier	First tier	Combined tier
Q1	6.67	6.67	66.67	46.67
Q2	100	93.3	100	100
Q3	40	33.33	60	53.33
Q4	93.34	86.67	93.33	80
Q5	86.67	73.33	100	80
Q6	100	100	86.67	86.67
Q7	93.33	100	100	100
Q8	86.67	86.67	100	86.67
Q9	40	40	80	80
Q10	73.33	73.33	86.67	86.67
Q11	100	100	100	93.33
Q12	73.33	53.33	86.67	66.67
Q13	100	46.67	93.34	66.67
Q14	80	53.33	86.67	66.67
Q15	86.66	53.33	100	66.67
Q16	66.67	53.33	73.34	60
Q17	53.33	53.33	86.67	80
Q18	26.67	20	46.67	33.33
Q19	100	6.67	100	33.33
Q20	100	93.33	100	100
Average	75.33	61.33	87.33	73.33

The results in Table 4 show that the average percentage of correct answers for the first tier in the pre-test is 75.33 and in the post-test is 87.33. In the combined tier, the average percentage of correct responses in the pre-test is 61.33, meanwhile, the percentage of correct responses in the post-test is 73.33. This result showed that the percentage of correct responses in the post-test is higher than in the pre-test. In the combined tier, the percentage of correct responses shows that students understand the environmental pollution concept. Of the 20-item questions, 11 questions show results above the class average, while 9 questions show results below the class average. In a multiple-choice test with four possible choices, the chance of guessing the correct answer is 25%. But, in TTMCT the chance of guessing is 6.25%. By reducing the probability of guessing from 25% to 6.2%, the students' ability to guess can be reduced. The first tier of each item in the test is a multiple-choice question related to the proportional statement, and the second tier of each item consists of a series of multiple-choice reasons for the answers to the first level. The student's answer to an item is considered correct if the student chooses the correct answer and the correct reason. Items from the TTMCT were evaluated for the correct and incorrect response combinations selected by the students. Following the research of Wang and Zheng (2021), it was found that EPGBL can improve students' understanding of environmental pollution concepts in science learning. This statement is also supported by the research of Emerson et al. (2020) which states that digital game-based learning provides a learning experience that makes it easier for students to find concepts in learning.

The learning experience of understanding concepts can be obtained by students when using EPGBL. The features in the EPGBL support students to be able to improve students conceptual understanding of the materials menu. In this feature, students can understand material related to environmental pollution such as the definition of pollution, types of pollution, and pollution prevention. The material is equipped with pictures so that students can easily imagine the material being studied. On the material types of pollution, equipped with pictures and examples in daily life. So that students will find it easier to find learning concepts in environmental pollution material associated with the surrounding environment and daily life. Meanwhile, the material for dealing with pollution contains an explanation of how to control pollution in various ways and pictures. An example of material on the EPGBL is presented in Figure 4.

Figure 4. Materials menu on EPGBL

In addition to the material menu, EPGBL also has a quiz feature related to environmental pollution material. Besides being able to measure students' knowledge of the material, this quiz can also improve students' conceptual understanding of the environmental pollution concept, because after answering questions on the quiz, students will immediately get the score and provides the correct answer. There are 15 multiple-choice questions related to environmental pollution with 4 alternative answers. An example of a quiz on the EPGBL is presented in Figure 5.

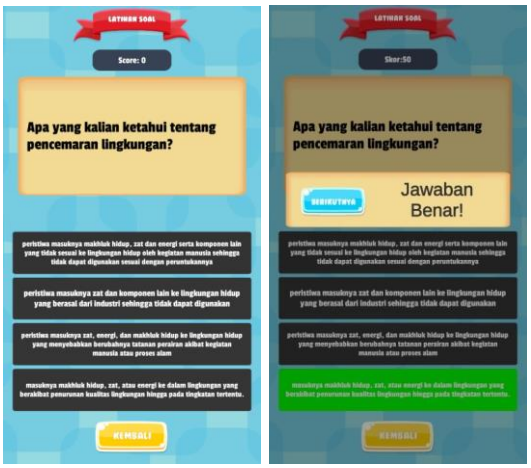

Figure 5. Quiz on EPGBL

Figure 5 show that if the user answers correctly or incorrectly, then there is a right or wrong notification so that the user can find out which answer is right or wrong. In addition, the user can also find out the score that has been obtained.

Students' Environmental Awareness

The General Ecological Behavior Scale (GEBS) formulates the dimensions of environmental awareness behavior, one of which according to Kaiser and Wilson (2004), can generally be grouped into 6 dimensions of environmentally awareness behavior: energy conservation, transportation and mobility, waste avoidance, consumerism, recycling, and vicarious, social behaviors toward conservation. One of the efforts to improve students' environmental awareness is through the implementation of learning media in junior high school students (Martia & Sugirin, 2019). In this study, each dimension of environmentally awareness behavior is divided into several statement items in the questionnaire.

The energy conservation dimension is a form of energy efficiency and saving behavior, as well as starting to switch to renewable energy. The dimensions of transportation and mobility are related to the choice of transportation for daily mobility, to reduce the impact of pollution and reduce fuel consumption. The waste avoidance dimension is related to reducing the use of items that can produce waste and using old items to be reused. The dimension of consumerism is related to the behavior of shopping for food for consumption, both pro-environmental food. The recycling dimension is related to the behavior of using unused items for other useful items. The vicarious dimension, social behaviors toward conservation related to behavior carried out by playing an active role in managing the environment in a community, increasing awareness. The results of the

analysis of students' environmental awareness characters after using EPGBL in the environmental pollution concept can be seen in Table 5.

Table 5. The average score of the students' environmental awareness character

Environment Awareness Dimension	Average Score	Criteria
Energy conservation	4.03	Very good
Transportation and mobility	3.56	Good
Waste avoidance	4.27	Very good
Consumerism	4.06	Very good
Recycling	3.83	Good
Vicarious, social behaviors toward conservation	4.10	Very good
Total average score	3.98	Good

The results of the analysis of students' environmental awareness obtained an average student score of 4.03 on energy conservation, 3.56 on transportation and mobility, 4.27 on waste avoidance, 4.06 on consumerism, 3.83 on recycling, and 4.10 on vicarious, social behaviors toward conservation. The average score of the students' environmental awareness character is 3.98 that include in the good criteria. Students' environmental awareness can be improved by educational games featured in EPGBL. The game on the EPGBL application is shown in Figure 6.

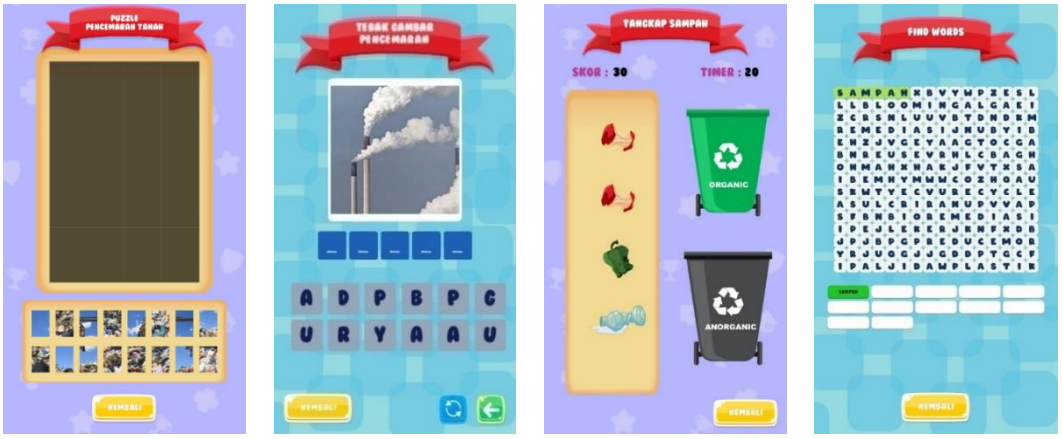

Figure 6. Feature Games in EPGBL

Figure 6 show the several educational games related to environmental pollution were developed in the form of (1) puzzles, (2) guessing pictures, (3) catching trash, and (4) finding words. Each game in the EPGBL application has instructions so that users know how to play the game well. In the puzzle game, there are 3 types of pollution in the puzzle. Users are asked to sort the image pieces randomly so that they become a complete image and relate to the type of pollution by moving the image pieces. The puzzle consists of 3 types of levels, ranging from easy, medium, to difficult based on the number of pieces of the picture. In the guessing game, there are 3 types of image pieces that will be guessed related to the type of pollution, the user is asked to guess what picture it is. Users simply answer by pressing a few letters in the box provided below the image.

In the trash catch game, users are given various images of falling garbage. Users are asked to catch garbage according to its type in the provided baskets (organic baskets and anorganic baskets). If it matches, it gets points, if it doesn't match, points decrease, and if it doesn't catch points, it doesn't increase or decrease. This game has a time limit of 30 seconds to get a high score. In the find words game, there are several hidden words, among others (readable and related to the concept of environmental pollution), the user is asked to search for the word by pressing and sliding the letters until they become the appropriate word. Twelve hidden keywords will be unlocked when the user can find the hidden words.

Questionnaire analysis revealed that after using EPGBL, students were more concerned about the environment. This is because by using digital game-based learning students will be directly involved in learning more about environmental care (Hosseini et al., 2019). It is impossible for people to completely eliminate pollution, but what people can do is try to minimize pollution or keep it under control by inculcating positive environmental care characteristics in the younger generation (Kalaycı, 2020). In EPGBL, students are not limited to reading the material but also doing the thinking process to understand concepts. This is because games in the EPGBL are designed as a medium for students to understand the concepts through guessing games (Gök &

İnan, 2021). Learning by applying game-based learning is a good approach to placing students in a meaningful and interesting practice environment, which can increase their motivation and interest in learning (Lin et al., 2018).

Some previous research also stated that game can improve conceptual understanding. Asfar and Asfar (2020) in his research conclude that case game-based learning with Quizizz is more effective than case base learning without Quizizz to improve students' conceptual understanding in mathematics by finding out the percentage of the correct answer. Fajjah et al. (2021) stated that QuizWhizzer assisted educational game design can improve students' conceptual understanding skills. Ristanto et al. (2022) also stated that FC-DGBL (Flipped Classroom–Digital Game-Based Learning) had a significant effect to enhance the conceptual understanding of the Genetics of bilingual secondary school students. In addition, digital based-learning games help students master concepts in learning (Henderson et al., 2020).

CONCLUSION

EPGBL is effective in improving students' conceptual understanding and environmental awareness. The average percentage of correct responses in the pre-test is 61.33, meanwhile, the percentage of correct responses in the post-test is 73.33. This result showed that the percentage of correct responses in the post-test is higher than in the pre-test. In the combined tier, the percentage of correct responses shows that students really understand the concept of environmental pollution concept. While in the questionnaire analysis revealed that after using EPGBL, students were more concerned about environmental awareness character. The average score of the students' environmental awareness character is 3.98 that include in the good criteria. Based on the research that has been done, suggestions that can be given are that researchers can add variations of educational games related to environmental pollution materials, and game-based learning-based media can be developed for other materials in science learning in junior high schools.

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