Design of LMS Integrated with Citizen Science and its Effectiveness in Improving Students' Awareness of Climate Change

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ABSTRACT

The Problem and Purpose of the Study. Although Learning Management Systems (LMS) have great potential to support integrated science learning based on citizen science, there is still a lack of LMS platforms specifically designed to facilitate student engagement in scientific projects related to climate change. As a result, opportunities to empower students as contributors of scientific data and to enhance their awareness of climate change issues remain suboptimal. This study proposes an LMS design for integrated science learning citizen science that facilitates activities or science projects to obtain data related to climate change.

Research Methods. This study adopted the Borg & Gall development model, which consists of four stages, namely: (a) analysis of development needs, (b) development of an LMS for integrated science learning with citizen science, (c) validation of the LMS, and (d) implementation in science learning. The number of participants was 84 students from junior high schools in Central Java. The statistical analysis used in this study is descriptive analysis and inferential analysis.

Results. The findings of this study indicate that: (a) the integration of citizen science into science education through LMS is very important to support the Sustainable Development Goals (SDGs), especially those related to sustainable education for climate change; (b) LMS validation conducted through expert assessment shows that LMS meets the necessary validity and practicality criteria, with a content validity score of 3.71 (in the highly valid category), construct validity of 3.72 (in the highly valid category), and an average practicality score of 99.67% by teachers (in the highly practical category) and 96.35% by students (in the highly practical category); (c)

Implementation shows that the developed LMS is effective in significantly increasing the average score of students' climate change awareness at $\alpha = 5\%$, the average n-gain of students' climate change awareness is in the moderate category, and the average n-gain of each indicator of students' climate change awareness is in the moderate to high category. The integration of citizen science in the LMS enables students to learn actively and contextually, which supports the improvement of climate change awareness. The positive response from students indicates great opportunities for further development of this LMS on other topics in the future.

Practical significance. The results of this study provide preliminary data on the integration of citizen science in science education, which can be used as input for teachers to continue implementing climate change awareness and exploring it through science education.

KEYWORDS

LMS, citizen science, science, validity, practicality, effectiveness, climate change awareness

For Citation: Siswanto, J., Huda, C., Nuroso, H., & Sari, N. L. D. M. (2026). Design of LMS Integrated with Citizen Science and its Effectiveness in Improving Students' Awareness of Climate Change. *Perspektivy nauki i obrazovania = Perspectives of Science and Education*, (3), 635–648. https://doi.org/10.32744/pse.2026.3.40

Received: 22 December 2025 | Approved: 24 March 2026 | Published: 30 June 2026

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INTRODUCTION

Climate change is one of the most pressing global issues and requires awareness and concrete action from all levels of society. The Intergovernmental Panel on Climate Change (IPCC) report confirms that human activities, especially greenhouse gas emissions, are the main causes of global warming and climate change [1]. Without serious mitigation efforts, global temperatures are expected to increase by more than 1.5°C by the middle of this century [2].

Education plays an important role in shaping scientific understanding and raising awareness of climate change. However, several studies show that students' climate literacy is still relatively low. For example, students tend to have limited understanding of the scientific causes of climate change, are more familiar with its general impacts, and often misunderstand the relationship between environmental issues and global climate change [3; 4]. Other studies confirm that although students show concern for the environment, their level of climate literacy is often low due to limited material in the curriculum and a learning approach that is still predominantly cognitive, rather than participatory [5]. This has an impact on students' attitudes and actions, which are not yet consistent in supporting climate change mitigation and adaptation [6; 7].

Science education should not only focus on cognitive knowledge, but also on developing awareness of environmental issues. Research shows that integrating climate change literacy into school curricula can increase students' environmental awareness and active participation in environmentally friendly actions [4; 7]. One innovative approach that can be used is the integration of citizen science into learning. Citizen science involves public participation in collecting and analyzing scientific data, so that students can become real contributors to scientific research. In this context, students can observe weather elements in their surroundings, which makes learning more authentic and meaningful. Citizen science can be an effective participatory strategy in increasing students' understanding and awareness of climate change. Through direct involvement in observing weather, temperature, or air quality data, students can see the real relationship between local phenomena and global issues [8].

Along with the development of digital technology, the Learning Management System (LMS) has become one of the important innovations in science education. LMS enables a flexible, interactive, and student-centered learning process, as it can be accessed anytime and anywhere via mobile devices [9]. LMS can be categorized as supporting mobile learning (m-learning) because many modern LMS are designed to be easily accessible via mobile devices such as smartphones and tablets, enabling flexible learning anywhere and anytime. Through features such as discussion forums, interactive quizzes, instructional videos, and automated assessments, LMS helps improve student motivation, learning outcomes, collaboration skills, and science literacy [10; 11].

An LMS for science learning that is integrated with citizen science will enrich the learning experience, because students will not only consume material, but also be actively involved in data collection, analysis, and scientific reflection. Research shows that the use of mobile learning combined with citizen science can increase student involvement in environmental monitoring and strengthen awareness of climate change issues [8; 12]. This is in line with the concept of contextual learning, where students are encouraged to relate science material to their daily lives [7]. Thus, LMS is not only a medium for knowledge transfer, but also a means of shaping critical, collaborative, and environmentally conscious attitudes in students.

This study was conducted with the aim of developing an LMS for integrated science learning with citizen science that is valid, practical, and effective in increasing students' awareness of climate change. In this study, students' awareness of climate change was measured through several indicators, including knowledge about the causes and effects of climate change, attitudes towards the importance of protecting the environment, concern for environmentally friendly behavior, and participation in climate mitigation and adaptation actions in their environment. Knowledge includes understanding greenhouse gases, global warming, and their impact on life [5]. Attitude reflects an individual's willingness to care for the environment and support sustainability policies [7]. Concern is manifested in daily behaviors such as energy conservation, plastic reduction, and the use of environmentally friendly transportation [13]. Meanwhile, participation refers to active involvement in environmental activities, such as reforestation, waste management, or citizen science projects [8].

Based on a review of various sources, it can be concluded that students' climate change literacy remains low and requires a more contextual, participatory, and experiential learning approach. Conventional science learning, which emphasizes cognitive aspects, is unable to consistently improve scientific understanding, awareness, or pro-environmental behavior. Integrating citizen science into learning, particularly through the use of digital technologies such as a Learning Management System (LMS), emerges as a potential solution because it can engage students in scientific observations, environmental data collection, and reflection on climate change phenomena. Previous research findings indicate that LMS and mobile learning can increase learning motivation, collaboration, and scientific literacy, while citizen science can strengthen awareness and concrete actions on environmental issues. Therefore, developing an LMS integrated with citizen science is considered essential to create more meaningful, interactive learning that impacts climate change awareness.

This article aims to explain the development and testing of the validity, practicality, and effectiveness of an LMS integrated with citizen science for science learning in increasing students' awareness of climate change. To achieve these objectives, this research describes the development of an LMS that facilitates citizen science activities, such as observing weather elements, recording environmental data, and analyzing data related to climate change. The development was conducted using an educational development research approach, including the following stages: analysis of development needs, development of an LMS for integrated science learning with citizen science, validation of the LMS, and implementation in science learning. Student awareness of climate change was measured using indicators of knowledge, attitudes, concern, and participation in mitigation and adaptation actions. Data collection techniques included questionnaires, observations, and knowledge tests, while data analysis was conducted descriptively and inferentially to assess improvements.

RESEARCH METHODS

This study adapts the Borg & Gall development model [14]. In its implementation, this study consists of four main stages, namely analysis of development needs, (b) LMS development, (c) LMS validation, and (d) implementation in science learning. The following is an overview of the activities carried out in each stage of the study.

Development Needs Analysis Stage

At this stage, a literature study was conducted on the use of LMS in science education and citizen science. After that, a survey was conducted on the needs of students and teachers regarding digital learning media, including obstacles in science education. In this stage, a Focus Group Discussion (FGD) was also held with teachers to map the competencies, materials, and indicators of climate change awareness that needed to be included in the LMS. The findings from this activity were utilized in the LMS development process. Previous studies have confirmed that needs analysis is very important to ensure that learning tools or media are appropriate to the context of students and teachers [9; 15].

LMS Development Stage

This stage includes: (a) Designing a user-friendly LMS interface; (b) Compiling science learning content integrated with citizen science (such as projects observing temperature, humidity, or daily weather); (c) Integrating interactive features: quizzes, discussion forums, observation data uploads, and reflections. A good LMS design must consider pedagogical, technological, and interactivity aspects to support contextual learning [10; 11]. One of the activities developed in the LMS is that students watch a video about climate change, then write down their observations about the visible impacts of climate change in their home environment, and upload their answers to the discussion forum. Students are required to respond to or comment on other students' answers or ask for clarification (at least one response or comment). In addition, students observe the impacts of climate change on the surrounding environment and enter the data into the LMS. The role of the teacher is to facilitate discussion, monitor student activities on the LMS, and provide feedback.

LMS Validation Stage

The validation process was carried out by science learning experts (validators) through an assessment of the construct validity and content validity of the developed LMS. The validity assessment included the quality of the display, navigation, and ease of use of the LMS, the suitability of the science content with the curriculum, its relevance to citizen science, and climate change issues. The experts also provided suggestions for the LMS. Revisions were then made based on the validators' suggestions to improve the LMS. Expert validation is an important step to ensure construct and content validity and support the effective use of the LMS [16; 17]. The average construct and content validity scores were categorized as follows: "Highly Valid (HV)" if the average score was $3.25 \leq P < 4.00$, "Valid (V)" if it obtained an average score of $2.50 \leq P < 3.25$, "Less Valid (LV)" if it obtained an average score of $1.75 \leq P < 2.50$, and "Not Valid (NV)" if it obtained an average score of $1.00 \leq P < 1.75$. Next, calculate the percentage of agreement (R) to determine reliability, $R = ((1-((A-B)/(A+B))) \times 100\%$, where R = coefficient of percentage of agreement, A = frequency of aspects observed by observers with high frequency, and B = frequency of aspects observed by observers with low frequency. Based on the calculation results, it can be said to be reliable if it has a percentage – 75% [18].

Implementation Stage in Science Learning

The final stage involved field trials with junior high school students, through the use of LMS in science learning, observation of student activities in citizen science projects through LMS features, measurement of its impact on students' awareness of climate change, and administration of questionnaires on student responses to the use of LMS for integrated citizen science science learning. The implementation of LMS can increase students' motivation, engagement, and science literacy when integrated with real-world context-based learning [8; 12]. The implementation in learning uses a one group pre-test and post-test design, namely: O1 X O2 [19]. In its implementation, before the student groups were given science lessons using LMS, they were given a pre-test on climate change awareness (O1). Then, they were given integrated citizen science science lessons using the developed LMS (X). After the learning process was complete, they were given a post-test (O2) with the same topics and questions as the pre-test.

The sample size was 84 students in three junior high schools in Central Java (classes X, Y, and Z). Each junior high school had 28 students. The sample was taken using the cluster random sampling technique. This technique is easier to implement because it is applied to groups or classes, so it does not take much time [19]. The selection of classes was done randomly so that the research results could still be generalized to the entire population.

The data collection methods and instruments in this stage were: (a) Observation of student activities using observation sheets; (b) The effectiveness of LMS for integrated citizen science science learning in increasing student awareness of climate change, using written tests; and (c) Student responses to the use of LMS for integrated citizen science science learning using questionnaire sheets.

The collected data was then analyzed to determine the effectiveness of the LMS. The analysis of the effectiveness of the LMS for integrated science learning with citizen science was carried out by statistically analyzing the average pre-test and post-test scores ($\alpha = 5\%$) using: (a) paired-sample t-test or non-parametric analysis Wilcoxon's test [20; 21]; (b) calculating the average n-gain using the formula: n-gain = (post-test score – pre-test score) / ideal score – pre-test score), with the following categories: high if n-gain ≥ 0.70; moderate if $0.70 >$ n-gain ≥ 0.30; and low if n-gain < 0.30 [22; 23]; (c) independent-sample t-test or non-parametric Mann Whitney U test [20; 21]; (d) calculating the percentage of relevant student behavior (relevant if > 60%); (e) calculating student responses to LMS for learning science integrated citizen science, responses are categorized as good if the average score percentage is ≥ 75% [24].

STUDY RESULTS

Results of Needs Analysis

The results of the needs analysis show that the development of an LMS for science learning integrated with citizen science is urgently needed to increase students' awareness of climate change. The latest international survey data, such as PISA 2018, reveals that Indonesian students' science literacy is still below average, especially in the applied and contextual aspects related to environmental issues [25]. In addition, other studies report that students' understanding of climate change is generally low and limited to general symptoms, thus requiring more participatory learning strategies [3,4]. Science teachers also stated the need for interactive digital media that can link science material to real issues such as temperature monitoring, rainfall, or air quality, so that students can play a role as citizen scientists in their environment [7]. By utilizing an integrated citizen science LMS, students can learn flexibly, upload environmental observation data, discuss, and reflect on the connection between local phenomena and global issues, which ultimately has the potential to increase climate awareness [10; 12].

LMS Design Development Results

The LMS developed is a mobile learning-based LMS that can be easily accessed using a PC or smartphone. The design of the LMS developed is presented in Figures 1 to 5.

Figure 1 LMS login page

Figure 1 shows the LMS login page. Students and teachers can log in using their respective usernames and passwords that have been provided previously in order to access the learning materials. Students' passwords are used to access learning materials and activities related to citizen science, while teachers' passwords are used to access the preparation, implementation, and evaluation of integrated science learning materials related to citizen science.

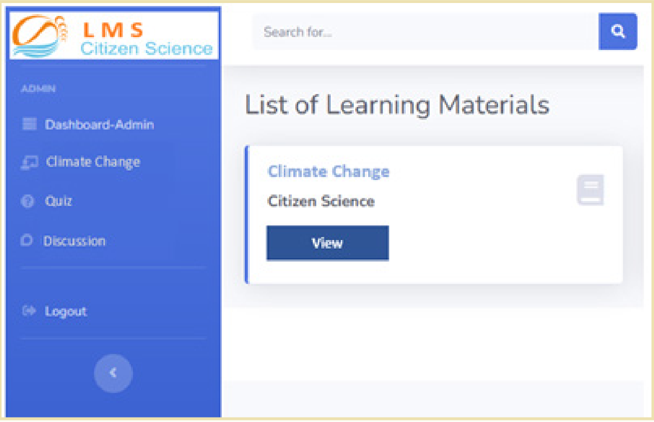


Figure 2 The initial display after login

Figure 2 shows the initial display after logging in. On the initial display after logging in, there are menus that support learning, namely learning materials, citizen science activities, discussion forums, quizzes, and the LMS logout menu. These menus can be accessed by clicking on the text. If students want to work on a citizen science project, they can select that menu. If students want to discuss in the LMS, they can select the discussion menu. Similarly, for quizzes, students can select that menu to improve their understanding of climate change.

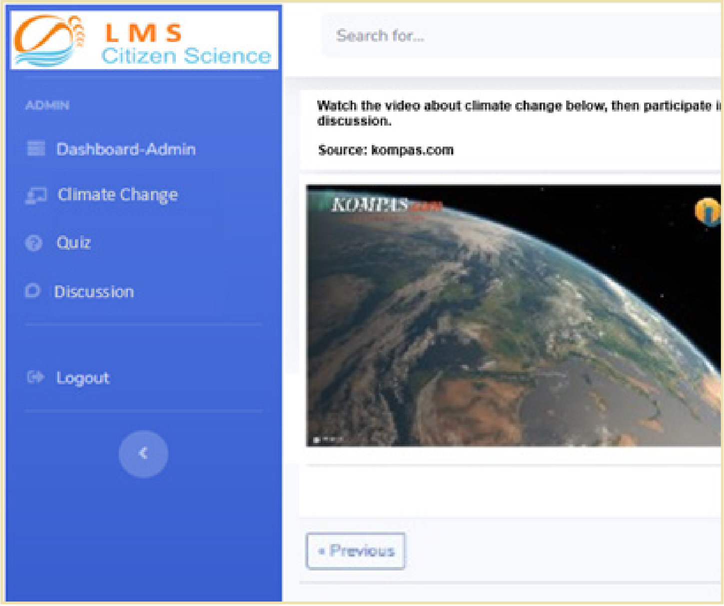
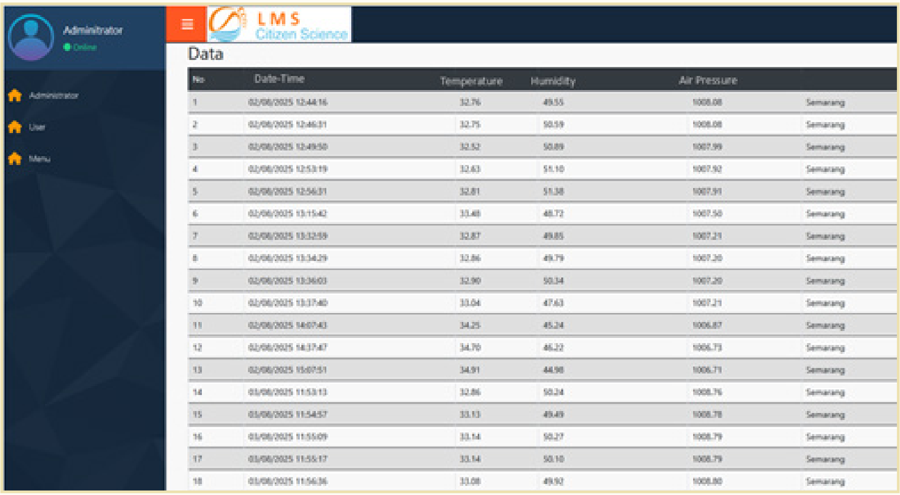


Figure 3 Learning materials in video format

Figure 3 presents learning materials in video format. Through this format, students are expected to obtain comprehensive information related to climate change. Videos can improve students' understanding of the material [26; 27].

In the citizen science menu, students will be involved in projects and activities to collect data on temperature, humidity, air pressure, and daily weather. The data is collected using appropriate measuring instruments and is facilitated and guided by teachers. The data obtained is then entered into the LMS. The data display in the LMS is as shown in Figure 4.



No	Date-Time	Temperature	Humidity	Air Pressure	
1	02/08/2025 12:44:16	32.76	49.55	1008.08	Semarang
2	02/08/2025 12:46:31	32.75	50.59	1008.08	Semarang
3	02/08/2025 12:49:50	32.52	50.89	1007.99	Semarang
4	02/08/2025 12:53:19	32.63	51.10	1007.92	Semarang
5	02/08/2025 12:56:31	32.81	51.38	1007.91	Semarang
6	02/08/2025 13:15:42	33.48	48.72	1007.50	Semarang
7	02/08/2025 13:32:59	32.87	49.85	1007.21	Semarang
8	02/08/2025 13:34:29	32.86	49.79	1007.20	Semarang
9	02/08/2025 13:36:03	32.90	50.34	1007.20	Semarang
10	02/08/2025 13:37:40	33.04	47.63	1007.21	Semarang
11	02/08/2025 14:07:43	34.25	45.24	1006.87	Semarang
12	02/08/2025 14:37:47	34.70	46.22	1006.73	Semarang
13	02/08/2025 15:07:51	34.91	44.98	1006.71	Semarang
14	03/08/2025 11:53:13	32.86	50.24	1008.76	Semarang
15	03/08/2025 11:54:57	33.13	49.49	1008.78	Semarang
16	03/08/2025 11:55:09	33.14	50.27	1008.79	Semarang
17	03/08/2025 11:55:17	33.14	50.10	1008.79	Semarang
18	03/08/2025 11:56:36	33.08	49.92	1008.80	Semarang

Figure 4 Display of data entered by students

Based on the data entered, students can view the graph and compare it with global data, for example from the website windy.com. The graph of the data entered by students in the citizen science project and global data is presented in Figure 5.

Based on Figure 5, students can learn by comparing data obtained from citizen science activities and global data. Students read the data to gain an understanding of climate change indicators based on data, graphs, and discussions with students and teachers. Learning with different representations can improve student understanding [28; 29].

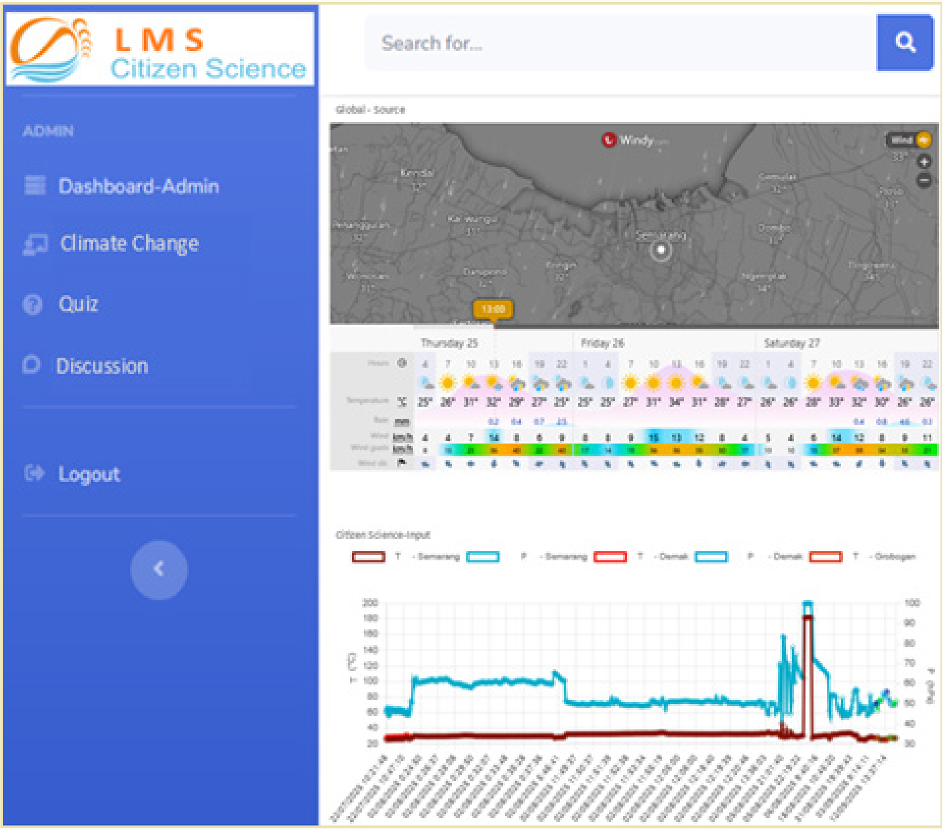


Figure 5 Display of data entered by students—graphs

Validity of the Developed LMS

The learning model requirements can be categorized as a high-quality product that meets content and construct validity. Content validity relates to relevance or currency, and construct validity relates to the consistency or logic of the LMS design [30; 31]. The content and construct validity scores for the developed LMS are presented in Table 1.

Table 1 LMS Validity Assessment Results

No	Aspecs	Validity		Reliabily	
		Score	Criteria	Coefficient percentage of agreement-R (%)	Criteria
Content validity					
1	LMS development requirements	3.68	Highly Valid	87.8	reliable
2	LMS is designed based on the latest knowledge	3.75	Highly Valid	90.5	reliable
	Average	3.71	Highly Valid	89.15	reliable
Construct validty					
1	Usability	3.68	Highly Valid	87.8	reliable
2	Fleksibility	3.75	Highly Valid	87.8	reliable
3	Support for innovative learning features (videos, discussion forums, quizzes, learning progress monitoring)	3.75	Highly Valid	90.5	reliable
4	Citizen science feature support	3.70	Highly Valid	87.8	reliable
	Average	3.72	Highly Valid	88.48	reliable

Table 1 shows that the LMS developed for integrated science learning with citizen science has very valid content and construct criteria. The average content validity score is 3.71 and the average construct validity is 3.71. These scores are >3.25 and are considered reliable with a percentage of agreement coefficient >75%. Although the LMS is considered highly valid, the validators also provided suggestions for improvement. Basically, these suggestions do not change the structure of the LMS. The suggestions from the validators are grouped into substantive and technical suggestions. The substantive suggestions are: (a) in discussion activities, instructions should be given so that students conduct discussions through the forum provided, such as an obligation to participate in discussions so that all students are involved; (b) in data input activities for observation results, there needs to be a limit on the amount of data input through citizen science activities. Meanwhile, the technical suggestions are corrections to typing errors. Subsequently, revisions were made to the developed LMS, which basically did not involve any significant changes to the structure of the LMS.

Implementation of LMS in Learning Science

This stage involved the implementation of an LMS for integrated citizen science science education in junior high schools. Data was collected on the practicality and effectiveness of the LMS.

a. Practicality of LMS

The practicality of the LMS is demonstrated by its operability for integrated citizen science science learning. The results of the observation show that the LMS has been designed to be used effectively in science learning in junior high schools. The results of the questionnaire given to teachers and students also show that during learning using the LMS, they did not experience difficulties in using the LMS (Table 2). Therefore, the developed LMS is declared to be operational or practical for use. However, using the LMS does not mean that there are no obstacles. The obstacles are non-substantive and can be immediately overcome, for example, when the internet connection is suddenly interrupted, it can be reconnected immediately so that it does not become a significant problem.

Table 2 Practicality of LMS

No	Aspec	User	
		Teacher	Student
1	LMS can be used easily	100.00%	96.88%
2	There are no significant problems in using the LMS.	100.00%	95.28%
3	LMS does not create new problems in the learning and teaching process.	99.02%	96.88%
	Average	99.67%	96.35%

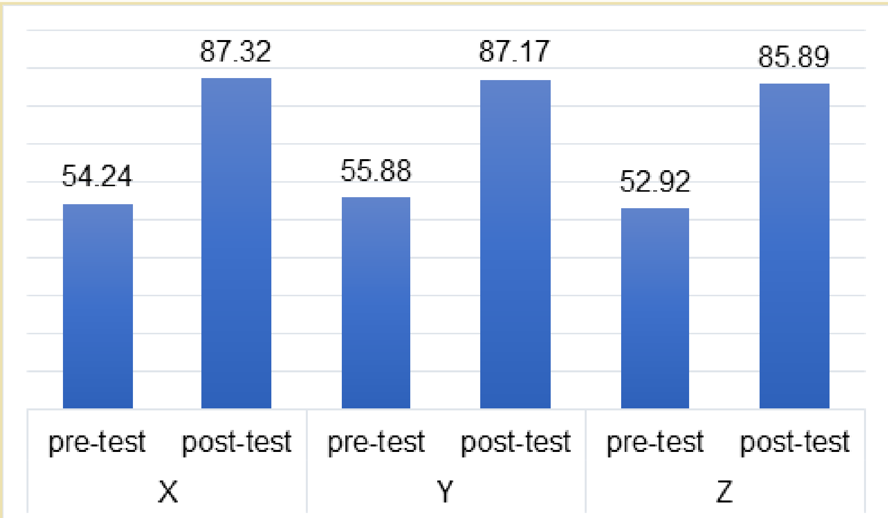


Figure 6 Graph showing the average pre-test and post-test scores for students' climate change awareness

b. Effectiveness of LMS

The average pre-test and post-test scores for students' climate change awareness are presented in Figure 6, and the analysis results are presented in Table 3.

Based on Figure 6, the difference between the average pre-test and post-test scores for students' climate change awareness can be seen. From these scores, further analysis was carried out.

Table 3 Results of Normality, Homogeneity, and Paired t-test/Wilcoxon test Calculations for Students' Climate Change Awareness Scores

Class	Test	∑	Min.	Max.	Average	Std.Dev	Normality p (α= 0.05)	Homogenity p (α = 0.05)	Paired t-test/ Wilcoxon test (α = 0.05)
X	Pre-test	28	45.34	60.22	54.24	3.65	0.106	0.104	t = -35.81; p< 0.001
	Post-test	28	79.86	91.67	87.32	2.81	0.097		
Y	Pre-test	28	49.88	60.08	55.88	3.12	0.066	0.322	t = -38.41; p< 0.001
	Post-test	28	80.92	91.17	87.17	2.51	0.141		
Z	Pre-test	28	43.71	58.52	52.92	3.98	0.140	0.003	z = -4.784; p < 0.001
	Post-test	28	74.38	89.88	85.89	2.76	0.079		

Table 3 shows that the pre-test and post-test scores for students' climate change awareness are normally distributed and homogeneous for classes X and Y. Meanwhile, class Z data is normally distributed but not homogeneous. The results of the paired t-test for classes X and Y, as well as the Wilcoxon test results for class Z, show that there is a significant difference between the pre-test and post-test scores for students' climate change awareness (p-value < 0.001). This means that there is an increase in students' climate change awareness after learning using LMS. Furthermore, an analysis of the increase in each climate change awareness was conducted to see its effectiveness in more depth. The results of this analysis are presented in Table 4.

Table 4 Results of n-gain calculations for each climate change awareness indicator

Class	Score	Climate Change Awareness Indicators				n-gain average
		Knowledge about the causes and impacts of climate change	Attitude towards the importance of protecting the environment	Concern for environmentally friendly behavior	Participation in climate mitigation and adaptation actions	
X	pre-test	3.82	3.01	3.32	4.01	0.66
	post-test	7.01	5.02	7.22	7.40	
	n-gain	0.62	0.67	0.69	0.68	
Y	pre-test	3.74	3.22	3.56	3.98	0.64
	post-test	7.12	5.12	7.12	6.98	
	n-gain	0.64	0.68	0.65	0.60	
Z	pre-test	3.76	3.40	3.40	4.11	0.67
	post-test	7.16	5.14	7.08	7.56	
	n-gain	0.65	0.67	0.66	0.71	

Table 4 presents the results of the n-gain calculation for the average of each climate change awareness indicator. The n-gain calculation results for each indicator show an increase in the high and moderate categories. The n-gain calculation results for climate change awareness among 10th grade students show an increase of 0.66 (in the moderate category). The details for each indicator are as follows: knowledge about the causes and impacts of climate change increased by 0.62 (in the moderate category); attitudes towards the importance of protecting the environment increased by 0.67 (in the moderate category); concern for environmentally friendly behavior increased by 0.69 (in the moderate category); and participation in climate mitigation and adaptation actions increased by 0.68 (in the moderate category). The results of the n-gain calculation of climate change awareness among students in class Y showed an increase of 0.64 (in the moderate category). Details for each indicator are as follows: knowledge about the causes and impacts of climate change increased by 0.64 (in the moderate category); attitudes towards the importance of protecting the environment increased by 0.68 (in the moderate category); concern for environmentally friendly behavior increased by 0.65 (in the moderate category); and participation in climate mitigation and adaptation actions increased by 0.60 (in the moderate category). The results of the n-gain calculation of climate change awareness among students in class Z showed an increase of 0.67 (in the moderate category). Details for each indicator are as follows: knowledge about the causes and impacts of climate change increased by 0.65 (in the moderate category); attitudes towards the importance of protecting the environment increased by 0.67 (in the moderate category); concern for environmentally friendly behavior increased by 0.66 (in the moderate category); and participation in climate mitigation and adaptation actions increased by 0.71 (in the high category).

Students' climate change awareness scores increased due to their involvement or relevant activities in the learning process using an LMS integrated with citizen science. Student activities were observed during learning, and the results are presented in Table 5.

Table 5 Student activities in learning using an LMS integrated with citizen science

No	Student Activity	Class X		Class Y		Class Z	
		frequency	%	frequency	%	frequency	%
1	Participate in citizen science projects	24.63	72.82	25.00	75.19	23.13	72.22
2	Participate in data collection	24.13	75.39	24.13	78.52	24.13	75.36
3	Participate in discussions on the LMS	23.73	72.82	23.85	71.22	22.78	71.08
4	Participate in classroom discussions	22.85	71.09	24.13	78.52	25.16	78.58

Based on Table 5, it can be said that in general, student activities during the learning process are relevant to the learning process using an integrated citizen science LMS. The learning process conditions students to learn about climate change through citizen science projects, data collection, and discussions on the LMS and in class. Student activity during learning has increased, and they appear enthusiastic. Student involvement in learning can significantly affect the quality of learning outcomes [32; 33].

After learning, students filled out a questionnaire regarding their response to the use of the integrated citizen science LMS. Student responses were related to: the novelty of the learning process using the LMS, the benefits for students, and their interest in the integrated citizen science LMS. Student responses are presented in Table 6.

Table 6 Student responses to the LMS for integrated citizen science science learning

No.	Aspecs	Student response		
		Class X	Class Y	Class Z
		Yes (%)	Yes (%)	Yes(%)
1	Novelty of the learning process using LMS	100.00	100.00	96.67
2	Novelty of media or science learning tools	93.82	93.78	90.00
3	Novelty of citizen science activities	100.00	100.00	96.77

4	Benefits of LMS in science learning	96.67	93.75	93.45
5	Benefits of LMS in raising awareness of climate chang	96.88	88.50	93.33
6	Interest in the next learning topic	96.88	100.00	100.00
7	Interest in other subjects	96.88	93.33	96.88
	Average	97.30	95.62	95.30

Table 6 shows that students responded positively to the LMS for integrated citizen science science learning. The average student response was > 75%, meaning that students supported and were interested in the learning process using the developed LMS. Students expressed interest in the LMS for learning on the next topic and other subjects. Students' positive responses to learning can increase student engagement, which in turn improves their learning outcomes [28; 35].

DISCUSSION AND CONCLUSION

The needs analysis in this study shows that the development of an LMS for science learning integrated with citizen science is very important to increase awareness of climate change among junior high school students. The 2018 PISA survey shows that Indonesian students' science literacy is still below average, especially in the applied and contextual aspects related to environmental issues [25]. Other studies reveal that students' understanding of climate change tends to be low and limited to general symptoms [32]. Therefore, learning strategies that emphasize active participation are essential [34]. Science teachers also stated the need for interactive digital media that connects science material with real issues in the environment, so that students can take on the role of citizen scientists who observe and report environmental phenomena [36]. The use of citizen science-integrated LMS allows students to learn flexibly and contextually, upload environmental data, discuss, and reflect on local and global phenomena through participatory learning mechanisms [26; 27].

The LMS, developed based on mobile learning, allows access through various devices such as PCs and smartphones. The LMS design includes a material menu, citizen science activities, discussion forums, and quizzes, all of which are designed to support interactive and reflective learning. The use of video as an effective learning medium improves understanding of climate change concepts, in line with the findings of Kay [26] and Hsin [27], which show that multimedia can increase student motivation and engagement in the learning process. The content and construct validation of the LMS obtained an average score of >3.7, indicating the suitability of the design to student needs and strong logical consistency [30; 31]. This indicates that the LMS has met good validity standards, with improvements that are technical in nature and do not interfere with the foundation of the developed LMS.

The practicality of the LMS can be seen from its ease of use by teachers and students, where most respondents did not experience significant obstacles in accessing and operating the LMS. Minor obstacles, such as unstable internet connections, can be immediately overcome, so they do not hinder the smooth learning process. Siswanto et al. emphasize that the practicality of learning technology is a major factor in the successful adoption of technology in the classroom [24]. An LMS with a user-friendly interface and easy access greatly supports the effectiveness of teaching and learning activities.

The results of the effectiveness test showed a significant increase in student post-test scores compared to pre-test scores in all climate change awareness variables, with a p-value of <0.001. Indicators of student knowledge, attitudes, awareness, and participation all showed significant increases with moderate to high n-gain categories. These findings reinforce the evidence that integrated citizen science LMS can effectively build student awareness of climate change issues. Research by Yildirim and Sen [31] and Zhao et al. [32], and Wagino et al. [33] supports the notion that learning involving participatory and contextual activities can improve student learning outcomes and social awareness, especially on relevant topics such as climate change. Similarly, the results of research by Sentosa et al. reveal that participatory education methods that integrate direct activities such as environmental management and community-based projects significantly improve students' understanding and awareness of climate change [37]. The study confirms that student involvement in real, contextual activities related to the local and global environment shapes positive pro-environmental attitudes and a willingness to contribute to climate change mitigation. This is consistent with previous reviews that experience-based learning and active participation are proven to be effective in building scientific understanding and social awareness of environmental issues, including climate change [38]. In addition, participatory education builds community capacity to adapt to the impacts of climate change through increased knowledge and social collaboration [39].

During the learning process, student engagement in citizen science activities and discussions on the LMS increased significantly, which had a positive impact on the quality of learning outcomes. Active student participation in the learning process can increase motivation and sustainable learning outcomes. Students' positive response to the LMS was evident from the novelty of the learning, the perceived benefits, and their interest in continuing to use the LMS in other topics or subjects. These results confirm previous findings that innovative and meaningful learning experiences significantly increase student engagement and motivation [34; 35].

The development and application of a mobile learning-based LMS integrated with citizen science in science learning significantly supports the achievement of the Sustainable Development Goals (SDGs), particularly SDG 4 (quality education) and SDG 13 (climate action). This LMS not only improves scientific literacy and 21st-century skills through active and participatory learning, but also fosters critical awareness of climate change issues through real data collection and contextual reflection. This is in line with research confirming that digital learning platforms and mobile learning are effective in building students' understanding and adaptive responses to the impacts of climate change, as well as strengthening their capacity as agents of environmental change [40; 41]. This approach is highly relevant to sustainable education efforts that target the development of scientific competence and environmental awareness as key assets in facing global challenges [41; 42]. Thus, the implementation of an LMS integrated with citizen science in the context of climate change learning makes a significant contribution to improving the quality of education and supports climate mitigation measures that are a global focus based on the SDGs agenda [42].

Based on the results of data analysis and discussion, it can be concluded that: (a) the integration of citizen science into science learning through LMS is very important to support the Sustainable Development Goals (SDGs), especially related to sustainable education for climate change; (b) LMS validation conducted through expert assessment shows that LMS meets the necessary validity and practicality criteria, with a content validity score of 3.71 (in the highly valid category), construct validity of 3.72 (in the highly valid category), and an average practicality score of 99.67% by teachers (in the highly practical category) and 96.35% by students (in the highly practical category); (c) Implementation shows that the developed LMS is effective in significantly increasing the average score of students' climate change awareness at $\alpha = 5\%$, the average n-gain of students' climate change awareness is in the moderate category, and the average n-gain of each indicator of students' climate change awareness is in the moderate to high category. The integration of citizen science in the LMS enables students to learn actively and contextually, which supports the improvement of climate change awareness. The positive response from students indicates a great opportunity for further development of this LMS on other topics in the future.

The implication of the development and implementation of this LMS is that it can be an effective alternative way to significantly increase students' climate change awareness. By facilitating active student engagement through real data collection, interactive discussions, and contextual reflection, this LMS not only improves learning outcomes but also shapes scientific attitudes and environmental awareness that are important for sustainability. Therefore, the implementation of LMS has the potential to be more widely adopted in science curricula and other subjects, and can be the basis for the development of innovative digital learning media that supports character education and 21st-century competencies in schools. In addition, it encourages closer collaboration between schools, communities, and scientific experts, which is an integral part of citizen science-based learning.

ACKNOWLEDGEMENT

The author would like to express gratitude to the Directorate of Research and Community Service, Ministry of Higher Education, Science, and Technology of the Republic of Indonesia for the financial support provided for this research through the Regular Fundamental Research scheme in 2025 (Contract Number: 127/C3/ DT.04.00.PL/2025 and 035/LL6/PL.04/2025).

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The authors declared no conflicts of interest