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Development of Metaverse Museum Learning Media on Environmental Material for High School Students

Ryan Haikal Firmansyah
Universitas Negeri Malang
E-mail: ryan.haikal.2207216@students.um.ac.id

Purwanto
Universitas Negeri Malang
E-mail: purwanto.fis@um.ac.id

Tuti Mutia
Universitas Negeri Malang
E-mail: tuti.mutia.fis@um.ac.id

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Abstract
Students' understanding of environmental problems around them is still relatively low, which is shown by the assumption that various environmental problems are common conditions and have been normalized in daily life. This condition results in low student concern for the impact caused, so learning media innovations that are able to provide a contextual learning experience and are in harmony with the learning characteristics of environmental geography. This research aims to develop metaverse-based learning media using Spatial.io and determine the level of feasibility and validity of the developed media. The research uses the Research and Development (R&D) method with the ADDIE model which includes five stages, namely analysis, design, development, implementation, and evaluation. The media presents contextual environmental problems in Malang City through a virtual environment equipped with authentic documentation, infographics, and problem-based learning activities. The validation results showed that the media obtained a score of 85% from media experts with a very feasible category, while the validation of material experts obtained a score of 81% with a very valid category. In addition, the results of the trial for students obtained a score of 80% with a feasible category. Based on these results, Spatial.io-based learning media is declared feasible to be used in the learning process because it is able to support students' understanding of environmental problems through a more interactive, contextual, and immersive learning experience.

Keywords: metaverse learning, spatial.io, geography education, environment, interactive media

INTRODUCTION

Geography learning has an important role because it not only emphasizes mastery of spatial concepts and facts, but also focuses on developing geographical thinking skills. These abilities allow students to understand the relationship between humans and the environment, analyze various spatial phenomena at various scales, and apply geographical concepts to study and solve problems that occur in real life. Thus, the development of geographical thinking skills is one of the main goals of geography education to form students who are able to face various social, environmental, and global challenges critically, analytically, and responsibly (Bendl et al., 2025).

Environmental material in geography learning has characteristics that are contextual, integrative, spatial, and problem-solving-based. In environmental education materials, it is necessary to focus on efforts to be able to find the causes of environmental problems and not just be satisfied with seeing the symptoms (Van De Wetering et al., 2022). These characteristics can be seen from the discussion which not only focuses on the physical condition of the environment, but also examines the mutual relationship between humans and the environment, the factors that cause environmental problems, the impacts caused, and their management and preservation efforts at various spatial scales, ranging from the local to global levels (Rohsulina, 2026)

Environmental materials require contextual learning because environmental issues are basically directly related to the real conditions experienced by students in their daily lives, such as pollution, waste management, floods, land use changes, and slums. By relating learning materials to environmental problems around students, they not only understand concepts theoretically, but are also able to connect knowledge with real experience, analyze the causes and impacts of a problem, and formulate relevant solutions. The contextual approach also encourages students' active involvement in the learning process thereby improving critical thinking, problem-solving, and concern for the environment (Welerubun et al., 2022).

The geography learning process in the classroom is still dominated by a teacher-centered learning approach. This approach is the main strategy in delivering material (Amiruddin et al., 2023). The dominance of the teacher's role in learning has caused students' active participation, both in the form of discussions, questions and answers, and feedback, to not have developed optimally due to the lack of two-way interaction between teachers and students (Sinaga, 2024). So that the learning activities carried out in the classroom feel monotonous and uninteresting for most students. Although the lecture method is considered to convey information to students directly, it often fails to provide a stimulus or stimulus for active participation for students and meaningful two-way interaction (Rosy et al., 2026). Students often become passive recipients of information, while limited classroom interaction reduces motivation and hinders teachers from effectively assessing students' understanding.

Based on observations made in class, students tend to understand theories about the environment, but are not able to recognize the problems that occur in the surrounding environment. This happens because students are able to master the concept of environmental material but are not followed by the development of cognitive skills and environmental literacy (Cahyani et al., 2025). The ability to recognize environmental problems requires the skills to identify, analyze, evaluate, and relate the concepts learned to real-world conditions in the field. If the learning process still focuses on mastering the material theoretically without providing a contextual and problem-based learning experience, students tend to only remember concepts, but have difficulty when they have

to apply them to identify environmental phenomena around them (Napitupulu et al., 2025).

Contextual learning is very important in education, especially in the process of learning activities. It bridges the gap between theoretical knowledge and real-world application (Budiarto et al., 2025). In geography education, especially in environmental materials, students often have difficulty understanding abstract concepts without real examples. By basing the learning process with specific local realities such as analyzing the environmental conditions and spatial planning of an area, students can directly understand and relate the subject matter to the environment around them (Bramasta & Andriani, 2026). This relevance changes what was initially passive students to more active with meaningful learning. Students do not only memorize definitions, but rather they develop critical thinking skills spatially or spatially. Therefore, it is possible for students to understand the direct impact of human activities on the local ecosystem that exists around.

Various studies show that metaverse media can increase student motivation, interaction and understanding. According to research by Sá & Serpa (2023) environmental learning needs to use the metaverse because the characteristics of environmental materials require students to observe real phenomena, understand the relationship between humans and the environment, conduct explorations, and analyze the causes and impacts of a problem contextually. According to research by Cho & Park (2023) found that metaverse-based environmental learning helps students visualize abstract environmental changes without direct field observation. However, their study focused on global issues and provided limited interaction through 360° photos, without addressing local environmental problems.

The metaverse platform chosen in this study is spatial.io. In contrast to 2D media that focuses on narrative, spatial.io is an immersive and collaborative platform that allows for the easy creation of 3D virtual classrooms (Hidayati et al., 2025). Functional advantages spatial.io precisely answer the weaknesses of conventional media for Environmental materials. Spatial.io supports Immersive and Contextual Visualization. Teachers and students can upload, place, and interact with 3D models, videos, and data in one virtual space (Selamat & Adnan, 2025). This allows students to conduct virtual field trips to damaged ecosystems or disaster sites to create a sense of place and deep contextual understanding (Tulaskar et al., 2025). And also the advantage of using spatial.io as a metaverse is that it is designed for collaboration in real-time.

Unlike previous studies, the developed media provides a contextual learning experience by representing real environmental conditions in Malang City, enabling students to relate concepts to everyday phenomena. Authentic field photos, interactive infographics, and free exploration enhance students' understanding of environmental issues while promoting curiosity and independent learning. The presence of avatars as user representations creates a more immersive learning experience, while virtual discussion facilities allow for interaction, collaboration, and exchange of ideas between students in real time.

This research aims to develop metaverse-based learning media using spatial.io as a means to increase students' understanding of environmental problems around them. The development of this media is based on the condition that some students are not able to recognize various environmental problems that occur in the area where they live, so their understanding of the causes, characteristics, and impacts is still limited. Therefore, learning media is designed by presenting contextual environmental conditions through

virtual environment visualization, authentic documentation, and supporting information so that students can directly observe the phenomena studied. Through an immersive and problem-based learning experience, it is hoped that students will not only be able to identify environmental problems around them, but also understand the impact they have on social, economic, and environmental aspects, so that they will grow awareness and concern to participate in environmental conservation efforts.

METHOD

Research Design

The type of research used in this study is Research and Development (R&D). The ADDIE model was chosen because it provides systematic stages from analysis to evaluation so that it is suitable for use in the development of learning media (Spatioti et al., 2022). The product development carried out is in the form of learning media using Spatial.io. There are stages in development consisting of Analysis, Design, Development, Implementation and Evaluation. The Analysis Stage was carried out by involving 31 students in grades XI-8 at SMAN (*Sekolah Menengah Atas Negeri*/ State Senior High School) 7 Malang City to analyze the need for the required learning media supported by spatial.io. The design stage is carried out by preparing a design in the form of a prototype of learning media in accordance with needs analysis data to produce a valid and feasible product according to the needs that have been identified. The development process begins with the design that has been prepared at the previous stage to be realized into a real product that starts with the creation of media in spatial.io and Canva, in addition to that the media will be tested through validation from media experts and also materials. At the stage of implementation of the media that has been developed, it begins to be applied in real learning situations. Products that have passed the validity test by experts are then tested on students, with teachers using the media that has been prepared. And at the evaluation stage, it is carried out by perfecting the final product of the media that has been developed.

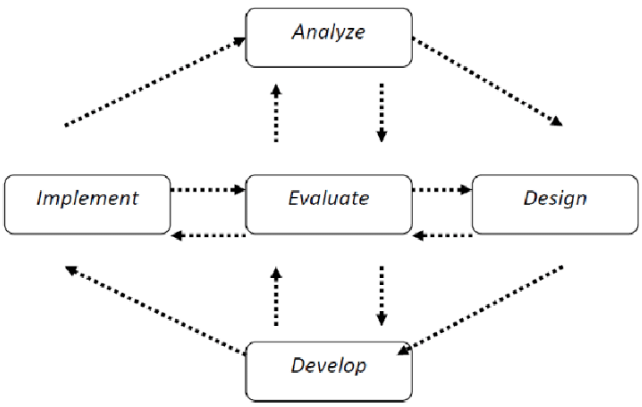


Figure 1. ADDIE Research and Development Steps

Data Collection Technique

The data collection technique in this study was carried out by random sampling because the selection was carried out randomly. The data collection technique was carried out using a closed questionnaire to obtain information about students' learning style preferences, obstacles faced in learning geography materials, learning media that have

been used, and the types of learning products that are expected to support their learning process. During the development stage, validation tests are carried out to find out whether the developed media is feasible or not feasible. The experts who validate the developed media are material experts and media experts. The instrument used in data collection is in the form of a validation questionnaire that serves to assess the feasibility level of the developed product. The data obtained in this study consists of two types, namely quantitative data and qualitative data. Quantitative data was obtained from the results of the questionnaire distribution as well as the validation assessment score used to evaluate the feasibility and practicality of the developed media. Meanwhile, qualitative data was obtained from suggestions, inputs, and responses provided by validators and respondents as considerations in improving the product. Furthermore, quantitative data is analyzed using the Likert scale by referring to the predetermined analysis formula. The explanation of the assessment categories on the Likert scale is presented as follows.

Table 1. Scoring guidelines

Answer Categories	Score
Strongly Agree	5
Agree	4
Enough	3
Disagree	2
Strongly Disagree	1

Data Analysis

The data analysis technique was obtained from media feasibility test instruments, material expert feasibility tests, and responses from students. The score obtained will be entered into the following formula.

$$x = \frac{the\ total\ score\ obtained}{maximum\ total\ value} \times 100$$

Description:
x= percentage of media eligibility

After getting the scoring score, look for the average using the following formula.

$$x = \frac{\Sigma x}{N}$$

Description:
x = average
Σx = sum of values
N = number of raters

The quantitative data obtained was converted with the following assessment criteria.

Table 2. Assessment Criteria

Score Range (%)	Categories
81 – 100	Highly Feasible
61 – 80	Feasible
41 – 60	Fairly Feasible
21 – 40	Less Feasible
Score less than 20	Inappropriate

FINDINGS AND DISCUSSION

Findings

The product developed in this study is metaverse-based learning. With the development of this learning media, it makes it easier for teachers and students to teach and learn geography environmental materials. The development of learning media is carried out through stages in the ADDIE research and development model. The five processes are.

Analysis Stage

Table 3. Need Analysis Results

No.	Aspects	Score
1	Learning materials are difficult to understand	72.5
2	Learning in the classroom is boring	70
3	Teaching materials used	69.8
4	The use of modern media helps with the understanding of the material	86.3
5	Metaverse learning is more exciting	91.3

Based on the needs analysis, as many as 91.3% of students prefer to learn using metaverse media. Therefore, learning media that can meet learning achievement is needed. Metaverse-based learning has the potential to increase learning motivation and learning satisfaction (Yang et al., 2024). Learning activities carried out through metaverse media can also help students learn even better and can foster a learning attitude, a more developed mind and better self-efficacy (Hwang et al., 2023).

Data at the analysis stage were obtained through classroom observations, semi-structured interviews with geography teachers, and small group interviews with students. The interview was conducted using guidelines that contained questions about the media used, learning constraints, student characteristics, and the needs of the learning media. From the results of interviews conducted with teachers, when teaching, teachers still use the main media of PowerPoint and textbooks, and sometimes if it is possible for teachers to carry out learning activities outside the classroom. However, the analysis also found that teachers need innovative technology-based media to support students' needs related to the use of technology in classroom learning activities. In addition, students also show that the use of innovative media in learning activities needs to be involved to increase enthusiasm and interest in learning. Students also stated that it is easier to understand the material by using innovative media.

Through curriculum analysis, it is also known that SMAN 7 Malang City is oriented towards the Independent Curriculum which supports active and contextual learning. In addition, the school also tries to implement learning with a deep learning approach by carrying three main principles, namely Mindful Learning, Meaningful Learning, and Joyful Learning. Through the results of identifying the needs of teachers, students and the curriculum, it becomes the basis for the development of metaverse media using spatial.io to be a tool or medium for learning activities in the classroom.

Design Stage

The design stage is carried out based on the results of needs analysis that have been obtained from observations, teacher interviews, student interviews, and curriculum analysis. The results of the analysis show that learning media needs to be designed in

accordance with student characteristics, learning outcomes, and contextual learning principles in the Independent Curriculum. Therefore, the researcher conducted a review of the Learning Objectives (TP) and Learning Objectives Flow (ATP) of environmental materials to ensure that the content and learning activities in the media are in line with the competencies that must be achieved by students.

The main outputs of this stage are storyboards, navigation flows, and the Spatial.io interface design, with storyboards guiding content sequence, navigation, and user interaction. The media design includes virtual space layout, learning object placement, and the integration of infographics, photos, videos, and 3D assets to present contextual environmental phenomena. Through this design, students are expected to be able to explore the material more realistically than through conventional learning media.

The media design also pays attention to the aspect of interactivity by utilizing the avatar feature on the Spatial.io platform so that students can communicate, discuss, and collaborate in a virtual space as well as the learning process in the classroom. In addition, at the end of the metaverse space, a link to the questionnaire is provided as a means of obtaining student feedback on the media that has been used. The provision of these features aims to facilitate the product evaluation process at the implementation stage.

Development Stage

This stage is carried out by making product development in accordance with the needs analysis that has been made and then validated. In problem orientation, students are introduced to contextual problems that stimulate curiosity, motivation, and investigation to develop appropriate solutions. At this stage, students actively identify contextual problems by connecting them with prior knowledge, while face-to-face discussions enable teachers to facilitate investigation and collaboration. The direct interaction also supports the development of communication, critical thinking, and problem-solving skills which are the main goals of problem-based learning (Smith et al., 2022).

Organizing Students to Learn. After students understand the problems presented, the teacher directs them to organize learning activities through group formation, role sharing, and explanations of goals, tasks, and problem-solving steps. At this stage, students plan learning strategies, identify required information and resources, and collaborate with group members to support effective investigation and shared responsibility. Thus, students are not only prepared to seek information, but also trained to develop communication, cooperation, and decision-making skills as provisions in solving the given problems (Kaur & O'grady, 2024).

Guiding Individual or Group Research. After understanding the task, students conduct individual or group investigations through observation, data collection, source comparison, and discussion with teacher guidance. At this stage, the teacher plays the role of a facilitator who provides direction if students experience difficulties during the investigation process, without directly providing answers to the problems faced. Through these activities, students are encouraged to develop critical thinking skills, collaborate, evaluate information, and build knowledge based on evidence obtained during the investigation process (Kong & Lai, 2023).

Develop and Present Results. After the investigation, students analyze and present their findings, justify solutions with evidence, and receive feedback to strengthen conceptual understanding, communication, collaboration, and reflective thinking. In metaverse-based learning using Spatial.io, the presentation of results can be done through

virtual discussions between groups so that students can exchange ideas and evaluate alternative solutions to the environmental problems studied (Alt & Raichel, 2022).

Analyze and Evaluate the Problem-Solving Process. In the final stage, students and teachers reflect on the problem-solving process, evaluate both the solutions and learning strategies, and use feedback to improve conceptual understanding and critical thinking. In Spatial.io-based learning media, the evaluation stage can be carried out through virtual discussions and reflection on the results of the analysis that have been presented, so that students have the opportunity to improve solutions based on the evidence and input received (Razak et al., 2022).

Metaverse media spatial.io has an important role in supporting learning activities. The platform allows the creation of learning materials to be more interactive and immersive, such as simulations, photos, and videos. In addition, spatial.io can also be accessed anytime and anywhere by using an internet connection connected to the device used.

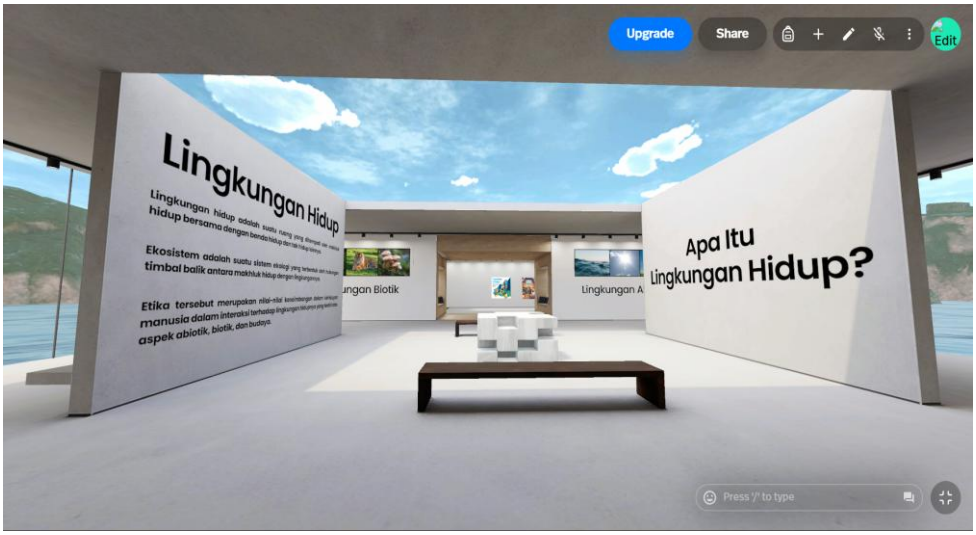


Figure 2. Environmental Concept Display

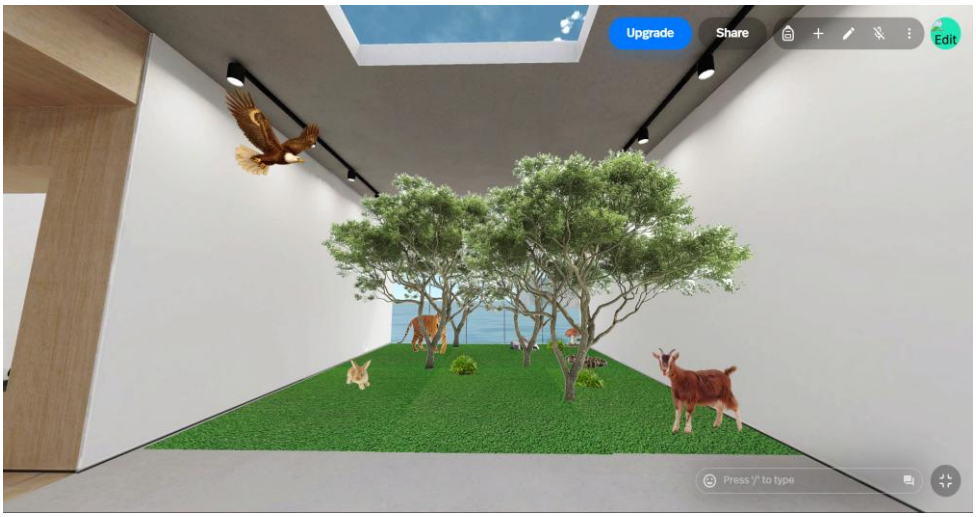


Figure 3. Environmental Ecosystem Display

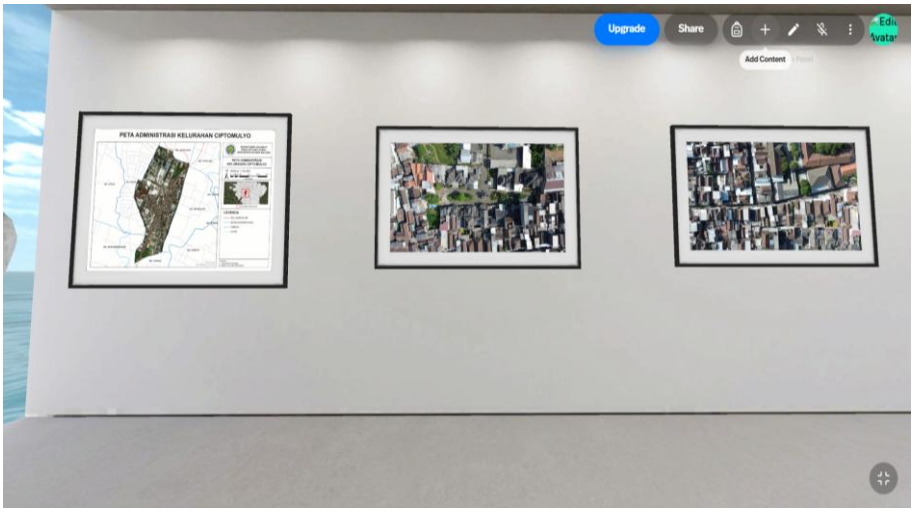


Figure 4. Display of Environmental Conditions in Malang City

In addition to presenting environmental materials comprehensively, this spatial.io-based learning media is also designed to provide a more contextual, interactive, and immersive learning experience. The media represents real slum environmental conditions in Malang City through a 3D virtual environment with authentic documentation, enabling students to freely explore and identify environmental characteristics, causes, and impacts. In addition, the media also provides a virtual discussion space that supports collaboration between students in analyzing problems and formulating solutions based on a problem-based learning approach (Nisa & Handayani, 2025).

The next stage is validation by media experts and also validation from material experts to assess whether the product is in accordance with the learning objectives. The following are the scores obtained from the validation of media experts and subject matter experts in the following table.

Table 3. Results of Media and Material Expert Assessment

Aspects	Percentage	Categories
Media Expert Validation	85%	Highly Feasible
Subject Matter Expert Validation	81%	Highly Feasible
Average	83%	Highly Feasible

The media developed initially has shortcomings, and needs to be revised before entering the implementation stage. In the initial phase of media validation it is recommended to fix some content that needs to be added. Media experts provide input on the placement of 3D objects so that they are not too close together, so that students' avatars have more room to move when navigating. Media experts also suggested the addition of a virtual directional marker feature so that students don't get lost when moving from one zone to another. These inputs were immediately revised to improve the quality of the product to be much more mature (Safitri et al., 2022). After revising based on the suggestions given, the validation results showed an increase with an average score of 85% which is included in the very feasible category. Therefore, the media developed has shown feasibility. The validation of the media that has been carried out will be continued

with the validation of the material to improve the quality of the material added to the learning media.

Subject matter expert validation is carried out to test the feasibility of the material in accordance with the Learning Outcomes and Learning Objectives The main purpose of validation is not only to assess the truth or falsehood of the material, but to ensure that the content of the media is completely aligned with the competencies that students must achieve (Respicio & Bauyot, 2026). The material expert recommended updating the information panels with recent environmental cases and contextual photos from Malang City. In response, the researcher revised the media by adding updated infographics and authentic local images. Based on the validation of the material that has been carried out, the material expert gave an assessment with an average of 81% which is categorized as very feasible.

Media and materials that have been validated can of course be continued to the next stage, namely the implementation stage. Media that have been validated received an 85% rating and are categorized as very feasible. And the material that has been validated gets an 81% assessment which is included in the very feasible category. Overall, the overall aspects of media and materials were obtained on average 83%, so that the media developed is very feasible to be implemented in learning activities.

Implementation Stage

At this stage, the researcher conducted a trial on the media that had been developed using spatial.io. The media implementation was carried out on November 15, 2024, the trial was carried out with 31 class students. All students in grades XI-8 use the media developed in spatial.io during the media implementation stage. The implementation stage evaluates the product's feasibility by observing student responses, effectiveness, and implementation challenges, followed by a student questionnaire. The main goal of this stage is to ensure that learning products can be used properly and correctly, and have a positive impact on the learning process. The implementation of the media can be seen in the following image.



Figure 5. Media Implementation Documentation

The results of the implementation show that metaverse-based learning media using the developed spatial.io is in accordance with the learning needs of students on

environmental materials. The integration of media with problem-based learning is able to encourage active involvement of students in the learning process through the presentation of contextual environmental problems in Malang City. A virtual environment equipped with authentic documentation, infographics, as well as three-dimensional representations allows students not only to understand concepts theoretically, but also to relate them to the real conditions they encounter in the surrounding environment. The interaction between students is seen to be more intense when they jointly analyze the causes and impacts of environmental problems based on the results of observations made in the virtual environment. Students who previously tended to be passive in conventional learning began to dare to express their opinions and analysis results through avatar representation, thus creating a more collaborative and participatory learning atmosphere. Of course, this is in accordance with previous research which shows that learning activities that integrate the use of spatial.io are able to increase student participation, student collaboration, and also student interest (Latif & Kamrozzaman, 2025).

Evaluation Stage

The last stage is the evaluation stage. The evaluation carried out at this stage is only to assess the response and level of student satisfaction with the spatial.io media that has been developed. The results of student feedback on the media that have been implemented are as follows.

Table 4. Student Feedback Survey Results

Aspects	Percentage	Categories
Material understanding	83%	Highly Feasible
Engagement and Fun of Learning Media	82%	Highly Feasible
Ease of Use	74%	Feasible
Media Display	80%	Feasible
Average	80%	Feasible

Based on the results of the assessment listed in the table, overall the media is in the decent category with an average score of 80%. Therefore, this spatial.io media is considered suitable for use in learning activities. The media developed can be said to have met the standards if it meets the valid categories in terms of content and media (Pratama et al., 2023). Student feedback indicated that the Spatial.io media supports contextual environmental learning, while its game-based design enables easy use through students' familiarity with digital games. Of course, this is in line with previous research which indicates that students are more accustomed to playing games than participating in classroom learning in general, educational games can also increase student involvement so that this is also followed by an increase in student learning motivation (Li et al., 2024). This is because the spatial.io media that has been developed is in line with the needs of students, and the available features also support learning activities, thus contributing to the feasibility of the spatial.io media that has been developed.

The spatial.io-based learning media developed supports learning that is in line with the needs of the curriculum. The learning media that has been developed is proven to be valid and feasible with a validity and feasibility level of 80%, therefore the media can be well received by users. In addition, the use of interactive features such as photos, videos, structured materials, and interactive discussion places supports student learning activities compared to conventional learning media. Of course, this research is in line with

research conducted by (Çeken & Taşkın, 2022) showing that learning media that combines various multimedia elements such as images, videos, structured texts, and visual elements is able to provide a more effective learning experience than conventional learning. This research also makes a practical contribution by showing that the ADDIE approach is effective in developing technology-based Geography learning media.

This research certainly has advantages as well as limitations, in the use of media that requires students to use an internet connection and supporting devices. Although the developed media has presented features that are able to help learning activities in the form of contextual media content with local environmental problems in the environment around students, especially in Malang City, the developed media has not been able to present media that can be accessed on the use of low-specification devices without the need for a good data or internet network. In addition, future researchers can also use similar learning media that can be used by all devices, both high and low specifications, and can also be accessed anywhere and anytime offline without having to be connected to the internet or good internet use. Thus, there is an opportunity for further researchers to develop metaverse-based learning media by improving various features and conducting effectiveness and practicality tests.

CONCLUSION

This research has succeeded in developing spatial.io learning media that raises environmental problems in Malang City, which is considered feasible and relevant to support environmental learning for high school students. Through the ADDIE stage, the media is designed using an analysis of student needs, curriculum, and characteristics. The media developed features materials, photos, videos, infographics, and relevant information that reinforce the learning experience for students concretely. The validation results obtained from the media showed a figure of 85% and for the validation provided by the subject matter expert showed a figure of 81%, which indicates that the media developed is categorized as very valid. Meanwhile, at the implementation stage, it shows that students give feedback on the media that has been developed with an average of 80%. Thus, the research has succeeded in achieving the goal of developing learning media that is valid and suitable for use in learning activities. However, the use of low-specification friendly metaverse media and low internet usage to access learning media should be considered for further development. In general, the spatial.io media developed has the potential to become an innovative solution in environmental learning at the high school level in Malang City.

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