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# Development of Ecoethnophysics-Based Virtual Reality Media using Glocal Wisdom Model to Train Scientific Literacy Through Local Wisdom of Gresik Windmills

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## ABSTRACT

***The problem and the aim of the study.*** 21st-century science education necessitates innovative approaches that connect scientific concepts to the real-life experiences of students. This study aims to develop ecoethnophysics-based Virtual Reality (VR) media by highlighting the local wisdom associated with Gresik windmills and integrating it into the Glocal Wisdom learning model as a means of enhancing students' Scientific Literacy. The integration of technology that provides real experiences with cultural content, through a learning process that emphasizes local and global connections, is expected to not only enrich conceptual understanding but also build environmental awareness and a more meaningful scientific identity.

***Research methods.*** The research employed the ADDIE development model, which included the needs analysis stage through bibliometric studies, the design and development of VR media using MileaLab software, expert validation, and implementation utilizing the Glocal Wisdom learning model through both limited and extensive trials. The research subjects consisted of students majoring in Physics, Biology, and Civil Engineering. The research instruments included a validation questionnaire, student worksheets, and pre- and post-tests of Scientific Literacy. Data analysis was conducted descriptively, qualitatively, and quantitatively using normality tests, paired T-tests, and N-gain calculations to assess improvements in Scientific Literacy skills.

***Results.*** The Ecoethnophysics Virtual Reality media was validated by experts, achieving an average score of 3.82, which is classified as highly valid, and was deemed practical for use in learning. The implementation of media in both limited trials and large-scale trials demonstrated a significant increase in students' Scientific Literacy, with an average N-gain in the moderate category (0.32–0.52). Student responses indicate that learning through VR provides an interesting new experience, strengthens emotional engagement, and fosters a connection between scientific concepts and local culture.

***Conclusion.*** Ecoethnophysics-based VR media has strategic potential as a contextual learning approach that integrates immersive technology with cultural values. This innovation is particularly relevant for further development, especially in experimental and interdisciplinary learning models, enabling it to address the challenges of 21st-century education through active, reflective, and locally based learning experiences.



## KEYWORDS

virtual reality, ecoethnophysics, scientific literacy, local wisdom, contextual learning, glocal Wisdom learning model, Gresik windmills

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# INTRODUCTION

The current global environmental crisis presents a significant challenge for 21st-century education, where science plays a crucial role in equipping young people to understand and address ecological issues [1]. Various phenomena such as climate change, land degradation, and ecosystem damage demand a new perspective in the teaching and learning process, especially in science education. Effective science education is no longer sufficient in merely conveying abstract concepts; it must also equip students with Scientific Literacy skills to understand, apply, and evaluate scientific information in real-world contexts [2]. This is where the importance of Scientific Literacy becomes particularly urgent. Based on the Programme for International Student Assessment (PISA) framework, Scientific Literacy encompasses not only understanding scientific concepts but also the ability to apply that knowledge to make evidence-based decisions in real-world contexts [3]. This indicates that Scientific Literacy also encompasses social and affective dimensions, particularly in the context of environmental issues that urgently require the integration of learning with sustainability concerns.

However, science education in Indonesia still has various limitations, one of which is the low Scientific Literacy scores of students in international studies such as the PISA [4]. This low performance is inseparable from the nature of learning, which remains predominantly theoretical and far removed from the reality of students' lives. Research by Khotimah et al. [5] demonstrates that contextual physics learning, achieved through STEM-based E-worksheets and local wisdom, can enhance student engagement. Arifuddin et al. [6] also emphasize the importance of teaching materials that are closely tied to students' real-life experiences, thereby enhancing their understanding of physics concepts. Similarly, Aryani et al. [7] prove that the integration of traditional games such as slingshots can bridge physics concepts with local culture, making learning more relevant and interesting. When science learning is not contextual and does not engage students' direct experiences, conceptual understanding becomes shallow and meaningless [8]. Many teachers find it difficult to design physics lessons that are relevant to students' daily lives, especially in relation to local environmental issues.

One potential approach to bridging the gap between abstract physics learning and the everyday realities of students' lives is the integration of local wisdom through an ecoethnophysics approach that synergizes physics, ecology, and local cultural values [9]. Local wisdom is not merely a traditional heritage, but also contains scientific principles relevant to modern scientific concepts, conveyed in a more down-to-earth language [10]. These cultural values can serve as entry points for learning, ranging from basic mechanics to concepts in energy and fluid dynamics. Research by Pilendia [11] emphasizes the importance of interpreting the integration of technology and local wisdom from a philosophical perspective on science, so that physics learning becomes more contextual and valuable. Meanwhile, Nasution [12] also shows that the concept of motion in local culture can be interpreted scientifically and utilized as a medium for learning physics that is rich in character values. This ethnophysics-based approach has been proven to improve students' understanding and engagement in physics learning.

Cultural diversity in Indonesia holds great potential as a contextual resource in physics education. Ethnophysical studies in local wisdom, such as *Tuak* Making and *Nitik Tuak* Culture in Tuban Regency [13], *Api Tak Kunjung Padam* in Pamekasan Regency [14], *Perahu Bidar* in Palembang [15], including the traditional practices of the Gresik community in utilizing wind energy through windmills. More than just local technology for irrigating rice fields, these windmills reflect the application of physics principles such as kinetic energy, thrust, and fluid dynamics that occur naturally in everyday life. When phenomena such as this are raised as a learning context, students not only learn concepts, but also see how science is present in their cultural reality [16]. However, the integration of local wisdom alone is insufficient without the support of learning media that is engaging and aligned with the characteristics of the current generation. This is where digital technology plays a role as a bridge between contextual learning experiences and the need for strong visualization.

Virtual Reality (VR) technology allows students to experience scientific phenomena involving visuals, spatial awareness, and active interaction [17]. Through VR, the workings of traditional windmills can be visualized as if students were actually inside the phenomenon [18], allowing them to explore physical processes directly in a digital environment that resembles the real world [19]. This encourages a deeper conceptual understanding, while activating experience-based learning and personal reflection. Previous research conducted by Azmi et al. [17] shows that VR is effective in interactively visualizing abstract physics concepts, increasing student motivation and understanding. Ubaidillah [20] found that VR-based learning of Hooke's Law changed students' perceptions of physics to make it more interesting and realistic. Meanwhile, Safarati & Fatma [21] concluded that VR can improve students' conceptual understanding and learning experiences, despite still facing technical challenges. It is at this point that the integration of advanced technology and local wisdom presents educational potential that is not only cognitively transformative but also shapes students' identities and concern for their environment and culture.

VR-based learning media that specifically highlight local wisdom and Scientific Literacy are still very limited. In fact, the combination of interactive technology and the ecoethnophysics approach has great potential to holistically improve Scientific Literacy, encompassing cognitive, affective, and contextual aspects. To fill this gap, this study aims to develop and implement ecoethnophysics-based VR media that highlight the local wisdom of Gresik windmills within the framework of the Glocal Wisdom learning model as a means of training students' Scientific Literacy. The main focus of the research is to test the validity of the developed media, analyze its practicality in the field, and assess its effectiveness in comprehensively improving Scientific Literacy skills.

## MATERIALS AND METHODS

This study uses a research and development (R&D) approach, adapting the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) as a systematic framework for designing and testing ecoethnophysics-based VR learning media. The ADDIE model is widely recognized and provides a structured flow that helps educators create engaging learning experiences [22]. Its five stages guide the development of content that is valid, practical for classroom use, and effective in achieving learning objectives, as shown in Figure 1.

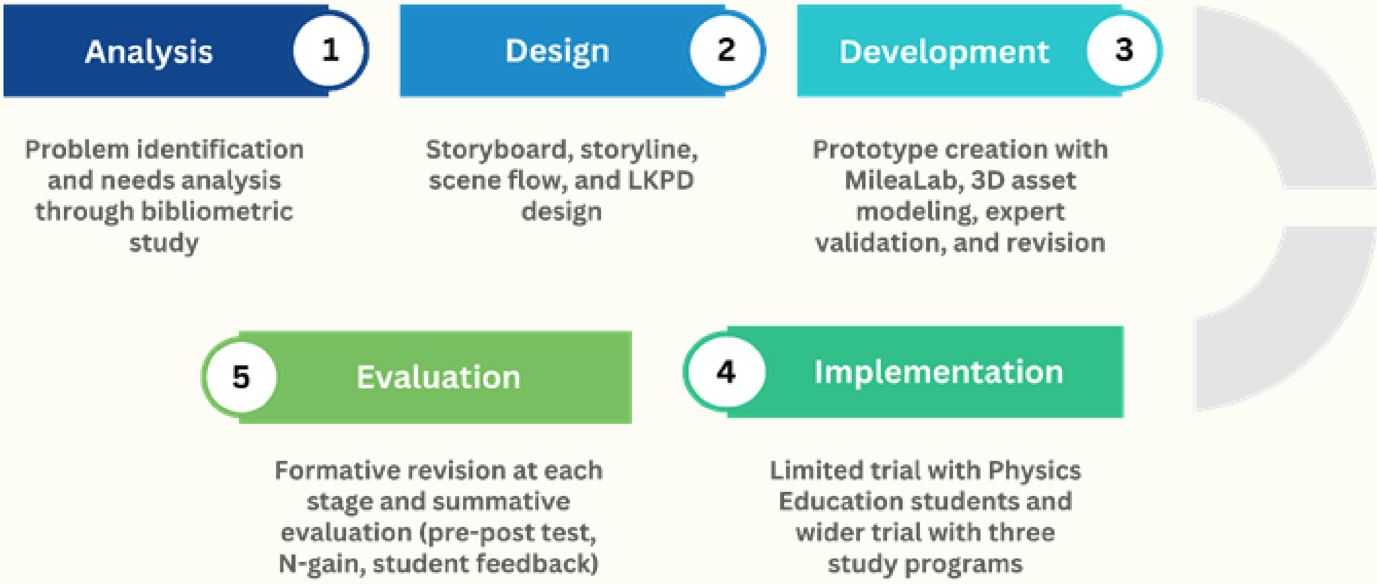


**Figure 1** Research Flow Chart

Based on Figure 1, the analysis stage was conducted to identify problems, learning needs, and potential local wisdom, specifically traditional windmill practices in the Gresik region. Information was obtained through literature studies, field observations, and limited interviews. The design stage involved formulating learning objectives, developing VR-based learning scenarios, and designing worksheets in accordance with the principles of ecoethnophysics and the PISA 2025 Scientific Literacy Framework. Entering the development stage, the Virtual Reality (VR) media were designed using the MileaLab platform, integrating visual, narrative, and interactive elements that represent the working system of traditional windmills and environmental physics concepts.

Validation was conducted by experts to assess the quality of the content and the suitability of the media. There were three validators involved in this process: Validator 1 and Validator 2, who are Doctors at Surabaya State University with expertise in Physics Education, and Validator 3, an Associate Professor at Surabaya State University with expertise in Physics Education. The selection of validators was conducted purposively, considering their expertise, academic track record, and professional experience in the field of physics education. Each validator has the competence to assess the substance of the material, instrument construction, language, and its integration with the local context. Furthermore, at the implementation stage, the media was tested on a limited and broad scale with students from three study programs to measure user responses and its potential impact on learning, guided by the Glocal Wisdom learning model syntax, so that the connection between local wisdom and global perspectives could be facilitated systematically.

To ensure the quality of the validation results, the level of agreement between validators was analyzed using the Percentage of Agreement (POA). POA is a statistical measure used to assess the consistency or suitability of assessments between validators when reviewing instruments, such as questionnaires, tests, and assessment tools. This method is widely used in instrument validation, where several experts assess the validity and reliability of media [23]. The validity score can be calculated by the mean of each score from validators while the reliability score represented in the Percentage of Agreement by Borich [24].

The research instruments used included validation questionnaires, observation sheets, practicality questionnaires, and Scientific Literacy tests. Data analysis was conducted through normality tests to ensure that the data distribution met parametric assumptions. Next, paired t-tests were conducted on three classes to compare the pre-test and post-test results. In addition, improvements in student learning outcomes were analyzed using normalized gain (n-gain), which was then visualized in diagram form for easier interpretation. The results of each stage of analysis formed the basis for continuous improvement, ensuring that the media developed was not only valid and practical but also effective in improving student Scientific Literacy through a contextual and locally based approach.

# RESULTS

Virtual Reality (VR) is an interactive technology that presents a three-dimensional simulation of a world, allowing users to experience a sense of being in a real environment [25]. In the world of education, this technology has begun to receive widespread attention due to its ability to provide learning experiences that were previously difficult to access directly, such as natural phenomena, microscopic spaces, or high-risk scenarios that would be impractical to carry out in the real world [26]. VR not only offers attractive visualizations but also allows for direct interaction with digital objects, enabling students to be more actively engaged in building their understanding [27]. By involving cognitive, visual, and affective aspects simultaneously, VR media has been proven to increase learning motivation, strengthen emotional involvement, and foster curiosity about the concepts being studied [28].

***Design Development Media***

The development of this learning media uses the MileaLab platform. This is due to its flexibility in intuitively creating VR-based applications. MileaLab offers a range of ready-to-use objects, a user-friendly interface, and comprehensive device integration support. However, not all objects relevant to local themes are available in its default library. Therefore, the Gresik windmill model, which is the core content of this media, was designed independently in 3D format and then registered in the MileaLab system for integration. The result is media that not only brings students into the digital world but also incorporates local culture as part of their learning experience, as shown in Figures 2.

Based on Figure 2, this media is designed with a narrative structure that flows smoothly. At the beginning of the session, students are introduced to the city of Gresik, complete with maps, background sounds, and visual descriptions that build context. Students will interact with visualizations and animations of windmills, listen to audio explanations, and read scientific information related to local cultural practices. The highlight of the learning experience is evident in the main scene in Figure 3, which depicts rice fields and traditional windmills used for irrigation, accompanied by dynamic animations of the blades' rotation that control the water flow. This interaction is supported by standpoint-based learning guidance, which helps students follow the learning sequence independently and reflectively.

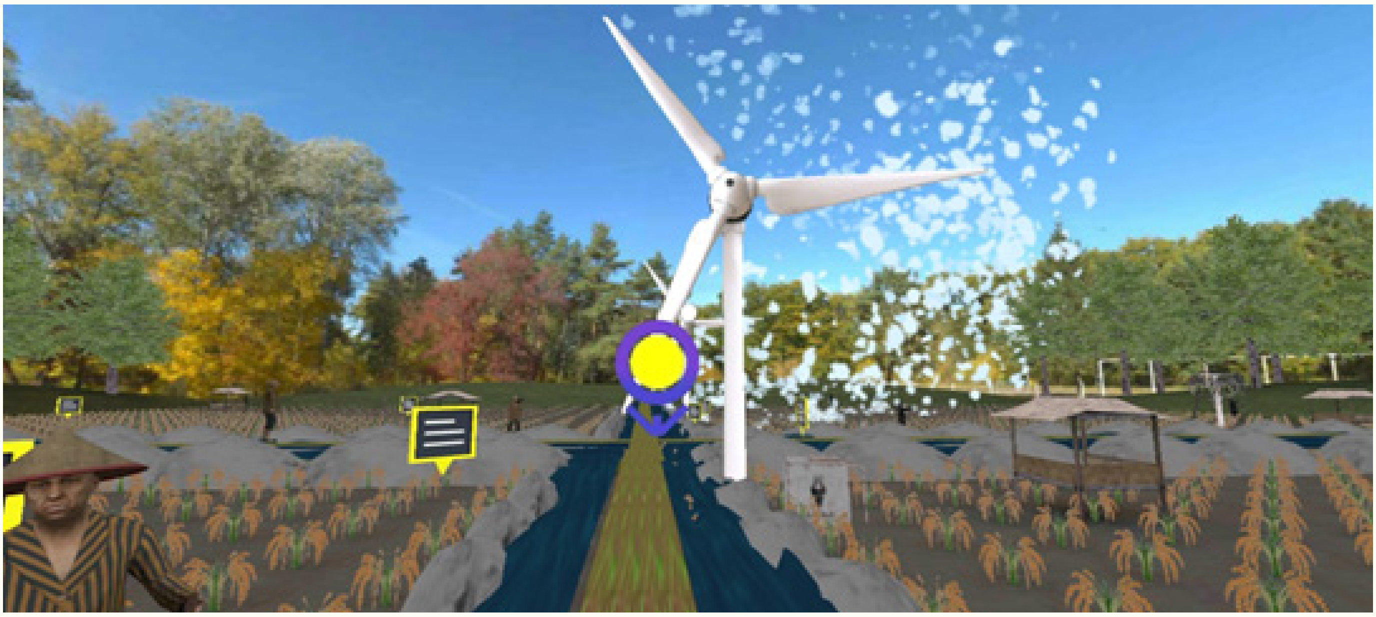

**Figure 2** Local Wisdom of Windmills in Gresik

As a supplement, investigative-based Student Worksheets were also developed to strengthen the connection between virtual experiences and students' scientific reasoning. These student worksheets train students' Scientific Literacy, where the questions in the student worksheets not only explore the physics of windmills, but also spark exploration of cultural and environmental values. Several sections of the student worksheets contain activities for observation, prediction, and interpretation of the phenomena displayed in VR. The combination of VR and ecoethnophysics-based student worksheets functions as a unified learning instrument that fosters holistic Scientific Literacy, integrating experience, reflection, and local meaning.

***Media Validation Results***

The developed media prototype was validated by three experts in Physics Education. Validation was conducted using a four-point Likert scale instrument to assess the aspects of language, media, material, and eco-ethnophysics. The validation results showed that the media obtained an average score of 3.82, as shown in Figure 3.

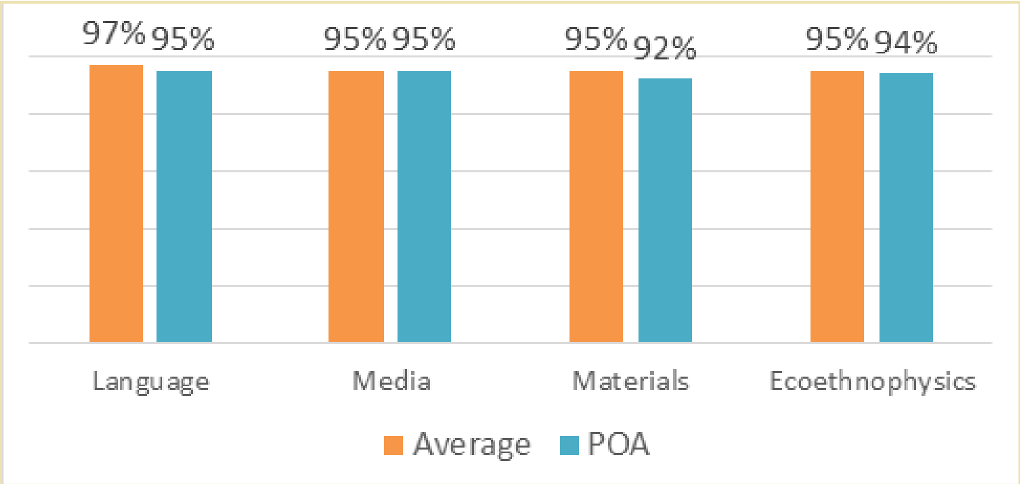


**Figure 3** Average and PoA Validation Results for Ecoethnophysics Virtual Reality Media

Based on Figure 3, the average validation results for the Virtual Reality Ecoethnophysics media showed a very high score with an overall achievement of 95.5%. All aspects of the assessment average were above 90%, making it highly valid. The language aspect received the highest score, namely 97%, which indicates that the clarity of terms, accuracy of sentence structure, and appropriateness of language use were excellent in supporting student understanding. Meanwhile, the media, material, and ecoethnophysics aspects each received an average score of 95%. These findings demonstrate that the media is not only visually appealing but also effectively integrates local wisdom into the context of physics learning, making it more meaningful.

Meanwhile, the Percentage of Agreement (PoA) analysis shows that the level of consistency among validators is in the range of 92–95%. This value confirms that the validation results have high reliability, as they exceed the minimum threshold of 75% that is generally used as a reference. Thus, the validation results, supported by very high average scores and consistent agreement among validators, show that the Ecoethnophysics Virtual Reality media have met the criteria of validity and reliability, and have strong potential for implementation in Scientific Literacy and local culture-based physics learning.

This input became the basis for the revision stage of development. Researchers added initial instructions in the form of an interactive tutorial that appears when the media is first opened, and enlarged several visual elements such as wind flow directions and physics concept markers. These improvements were made to increase accessibility and user comfort, thereby enhancing the effectiveness of the learning process. Figure 4 illustrates the results of the revised learning media.


**Figure 4** Revised Stand Point Results for Usage Instructions and Media Story Line

Figure 4 illustrates the initial design, which incorporates local elements of Gresik City, serving as an introduction to virtual exploration. The placement of avatars dressed in traditional clothing, visual backgrounds depicting city atmospheres, passing aircraft, and rice fields in the distance aims to visually introduce the cultural context from the outset. The strikingly colored navigation markers serve as standpoints to guide users along the designed flow, clarifying the story structure while strengthening the narrative flow of the media. The presence of map symbols and strategic locations is also a crucial element in supporting the connection between digital space and real geospatial space, a hallmark of the ecoethnophysics approach.

***Media Implementation and Evaluation***

The media implementation stage was carried out after the validation process was declared feasible, including a limited trial involving 15 Physics Education students from 2023 academic year. The limited trial was designed to assess the practicality of using the media, identify technical obstacles, and gather feedback from users [29]. Each student was asked to explore all available scenes in the VR media, interact with the displayed content, and complete the integrated worksheets. During the activity, students showed high enthusiasm, as the learning experience through VR presented a new atmosphere that they rarely encountered in conventional lectures. This fact reflects the results of limited trial that the media is highly practical based on the student's response. The most dominant feedback highlighted the need for concise instructions that could be easily accessed directly from within the application. In response, the researchers added brief interactive instructions at the beginning of the media. This situation is understandable, given that the application of VR in learning in Indonesia is not yet widespread; therefore, the element of novelty also strengthens the motivation and engagement of participants. This implementation process is supported by the application of the Glocal Wisdom learning model, whose learning phases are presented in Table 1.

**Table 1** Syntax of the Glocal Wisdom Learning Model [30]

| Phase | Teacher Activities | Student Activities |
|---|---|---|
| Phase 1: Phenomena Identification | The teacher presents local wisdom phenomena with a global context to the students and raises problems. | Students identify local wisdom phenomena and raise problems. |
| Phase 2: Concept Analysis | The teacher facilitates students to analyze scientific concepts in the presented local wisdom. | Students analyze and apply scientific concepts within local wisdom. |
| Phase 3: Scientific Inquiry | The teacher guides students to conduct scientific investigations, interpret data, and draw conclusions. | Students conduct scientific investigations, interpret data, and draw conclusions regarding the issues studied. |
| Phase 4: Discussion and Decision Making | The teacher facilitates students to discuss the results of scientific investigations and guides them to make decisions based on the findings. | Students discuss the results of scientific investigations and make decisions based on the findings obtained. |
| Phase 5: Reflection | The teacher guides students to evaluate the results of the scientific investigation and the learning process that has been carried out. | Students evaluate the results of the scientific investigation and the learning process that has been carried out. |

Glocal Wisdom learning model is a learning model that developed to increase the student Scientific Literacy based on PISA Science Framework 2025 using local wisdom and global issue as a content and context of the learning. Based on Table 1, the implementation process was aligned with the syntax of the Glocal Wisdom learning model, which includes the phases of Phenomenon Identification, Concept Analysis, Scientific Inquiry, Decision Making, and Reflection. Students were introduced to the local phenomenon of windmills in Gresik as a starting point for identification, then directed to analyze the inherent cultural values. Next, they conduct scientific investigations using VR simulations, interpret their observations, and relate them to physics concepts. At the decision-making stage, students are invited to develop data- and evidence-based arguments to explain the relevance between science and local wisdom. The final stage is reflection, which encourages students to evaluate their learning experiences, consider the contribution of VR to Scientific Literacy, and realize the importance of harmony between global knowledge and local cultural roots.

The success of the limited trial (highly practical) then became the basis for conducting a large-scale trial in October 2024, involving students from the Physics, Biology, and Civil Engineering Study Programs of 2024 academic year. The primary objective of the large-scale trial was to evaluate the effectiveness of Ecoethnophysics VR media in enhancing Scientific Literacy, particularly in the context of local wisdom-based environmental education. This activity further demonstrated the potential of VR as a means of interdisciplinary learning and collaboration, where interactive technology bridges scientific understanding with socio-cultural approaches. Documentation of the large-scale trial is presented in Figure 5.

Based on Figure 5, documentation of large-scale trial activities involving students from the 2024 Physics Education Study Program, 2024 Biology Study Program, and 2024 Civil Engineering Study Program, with various activities ranging from class discussions, presentations, and the use of ecoethnophysics-based Virtual Reality media. It is evident that students are not merely recipients of information but actively engage in discussions and collaborate, both in large and small groups. The use of VR in this activity provided a contextual learning experience based on local wisdom, which increased enthusiasm, trained critical thinking skills, and strengthened the connection between physics concepts and real-world phenomena. This documentation also confirms that ecoethnophysics-based media can be applied across study programs as an innovative means to enrich students' learning experiences in a more active and meaningful way.

**Figure 5** Documentation of Large-Scale Trial Activities by Students

The results of both stages of implementation demonstrate consistency, showing that ecoethnophysics-based VR media not only fosters emotional engagement among participants but also increases their sense of ownership of science as part of their culture. This finding aligns with the research of Makransky & Lilleholt [31], who emphasize that VR-based learning can provide a deeper and more memorable experience than traditional methods. Moreover, the integration of local values displayed in the media enriches the meaning of learning, while also emphasizing that Scientific Literacy cannot be separated from the social and environmental context in which learners exist. The results of extensive trials are also supported by quantitative data, which show a significant increase in participants' Scientific Literacy achievements, as presented in Table 2.

**Table 2** Results of Normality Tests using SPSS

| Assessment | Class | Sig.* | Conclusion |
|---|---|---|---|
| Pre-test | Experiment 1 | 0.325 | Normally distributed |
| | Experiment 2 | 0.329 | Normally distributed |
| | Experiment 3 | 0.008 | Not normally distributed |
| Post-test | Experiment 1 | 0.001 | Not normally distributed |
| | Experiment 2 | 0.804 | Normally distributed |
| | Experiment 3 | 0.912 | Normally distributed |

**Normality Test using the Shapiro-Wilk Test*

Based on Table 2, the results of the Shapiro-Wilk normality test show that most classes meet the normality assumption, except for Experiment 3 in the pre-test assessment, which shows a non-normal distribution. However, in the post-test assessment, Experiment 1 does not meet the normality assumption, while Experiments 2 and 3 show a normal distribution. These results provide an important basis for selecting statistical analysis methods, specifically between parametric tests for normally distributed data and nonparametric tests for non-normally distributed data, as presented in Table 3.

**Table 3** Paired T-test

| Class | Type of Statistical Test | Sig. | Conclusion |
|---|---|---|---|
| Experiment 1 | Nonparametric (Sign & Wilcoxon) | 0.00 | There is a significant difference |
| Experiment 2 | Paired Sample T-Test | 0.00 | There is a significant difference |
| Experiment 3 | Nonparametric (Sign & Wilcoxon) | 0.00 | There is a significant difference |

Based on Table 3, the consistent improvement across all experimental classes confirms that the effectiveness of the media stems not only from the ecoethnophysics-based VR technology aspect, but also from the use of the Glocal Wisdom learning model as its organizing framework. The syntax of Glocal Wisdom, which guides students from the introduction of local phenomena to reflection on global issues, makes the learning process more focused, so that improvement in achievement remains apparent even though the statistical analysis used differs in each class. This demonstrates that the media and learning model complement each other, where VR provides an engaging and immersive experience, while Glocal Wisdom ensures that the experience is linked to broader conceptual understanding and cultural values. Further analysis of student achievement improvement is visualized in Figure 6.

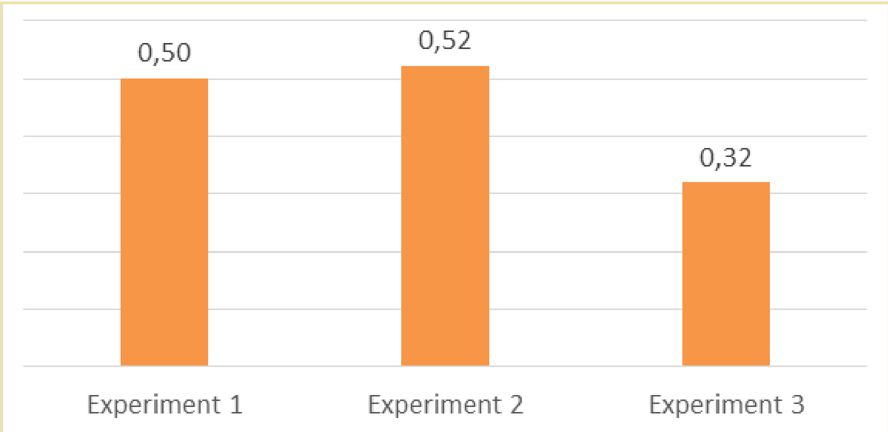


**Figure 6** Results of N-gain Analysis for Experiment 1, 2, and 3 Classes

Based on Figure 6, N-gain scores show variations in improvement between classes, with the highest achievement in the Experiment 2 class at 0.52 (moderate category), followed by the Experiment 1 class at 0.50 (moderate category), and the Experiment 3 class at 0.32 (moderate to low category). Analysis of the pre-test and post-test results shows a statistically significant difference ($p < 0.001$), with N-gain achievements ranging from 0.32 to 0.52. This variation was primarily influenced by the conditions in Experiment 3, where the students' high enthusiasm for exploring VR media led to a reduction in their focus on completing the worksheets. Although the improvement achieved was not in the high category, these findings confirm that the use of ecoethnophysics-based Virtual Reality can contribute positively to the learning process, both in terms of conceptual understanding and student engagement. The effectiveness of the media was most pronounced in Experiment 2 class, but it still had a significant influence on other classes, as reflected in the moderate achievement category, which demonstrates the media's success in linking virtual experiences with real phenomena based on local wisdom.

# DISCUSSION

The study results indicate that VR-based learning media innovations require a period of adaptation before they can be fully optimized. This aligns with research by Hake [32] and Kondrashev et al. [33], which shows that the effectiveness of new media grows as learners adapt. VR is more than just a means to transfer information; it also fosters a shift in students' learning patterns. Students move from passive to more active, reflective, and meaningful learning, especially when VR is combined with a culture familiar to them [34]. This shows that VR learning experiences bring new dynamics not only to conceptual understanding but also to emotional involvement and social interaction in science learning.

The finding demonstrates that the effectiveness of media extends beyond quantitative results to its alignment with the syntax of the Glocal Wisdom model. At the phenomenon identification stage, students are introduced to the Gresik windmill as a representation of local wisdom that can be studied using principles of fluid dynamics. This process is then followed by a virtual exploration, which allows students to examine how these concepts work in real-life situations. The next step, scientific concept analysis, helps students connect real experiences with abstract physics theories, while the global reflection stage leads them to understand that the local wisdom they have learned is actually related to the issue of renewable energy. Through this series, learning not only links science with culture but also shapes a critical awareness that local knowledge can contribute to global solutions, encouraging students to learn more actively, reflectively, and meaningfully.

The use of ecoethnophysics-based Virtual Reality presents physics learning that is far more contextual and meaningful. The integration of local wisdom from the Gresik windmill makes the concept of fluid not only understood as a formula, but also as a phenomenon that exists within the community, allowing knowledge to be more easily linked to everyday experiences [35]. This approach also strengthens students' scientific identity by fostering environmental stewardship and emotional closeness to inherited cultural phenomena [21]. In addition, the real experience provided by VR can increase the motivation and active involvement of students in learning, as shown in research conducted by Makransky & Petersen [34], and demonstrates how modern educational technology can be a means to build stronger epistemic agency [36].

The results align with global studies on the use of immersive technology in science education. Matovu et al. [37] conducted a literature review, finding that immersive virtual reality (IVR) can enhance students' conceptual understanding of scientific phenomena by providing a more authentic learning experience. Jiang et al. [38] also emphasized that VR/AR in STEM learning, particularly at the K-12 level, has experienced significant growth over the last six years, with a positive impact on motivation and the learning process. However, unlike previous studies that emphasized the role of VR in improving conceptual connections and scientific reasoning skills in general, this study provides added value through the integration of local wisdom as a bridge for learning. Specifically, the ecoethnophysics approach used here makes physics concepts not only studied as abstract theories, but also linked to cultural phenomena that exist in society, namely the Gresik windmill. This uniqueness demonstrates that the effectiveness of VR can be expanded not only in the cognitive realm but also in shaping students' scientific identity and fostering environmental awareness rooted in local culture.

Building on these perspectives, Wulandari et al. [39] highlight the importance of learning designs that foster critical thinking through contextual experiences. Afifah et al. [40] reported that the use of Virtual Reality media in learning can boost students' environmental problem-solving skills by up to 36% when implemented in classroom settings. Additionally, Ladjidji et al. [41] developed a VR-based approach on ethno-SDGs, which successfully increased student motivation and science literacy. Taken together, these findings further demonstrate that immersive technology can enhance learning and foster the development of 21st-century skills. Moreover, integrating VR in learning encourages a more participatory and interactive classroom, aligning with the values of sustainability.

The implementation of this media also faces serious challenges, where the high enthusiasm of students makes them more interested in exploring VR features than focusing on completing the Student's Worksheet. This condition causes an imbalance in the allocation of learning time, resulting in suboptimal written assignments, with some students even failing to complete the entire Student's Worksheet. As a result, the scores obtained do not fully reflect their conceptual understanding but are influenced by the limited time spent exploring the media. A similar situation is also confirmed by the research of Lestari et al. [42], which states that the use of immersive technology requires a more flexible classroom management strategy to prevent students' euphoria from hindering the achievement of learning objectives.

The main advantage of this medium is evident in its ability to integrate with the Glocal Wisdom learning model, which systematically guides students to connect local values with global insights. Through structured syntax, the learning experience becomes more meaningful because students not only understand the phenomenon of Gresik windmills in the context of physics, but also reflect on it as part of international energy and environmental issues. This kind of integration also expands the opportunities for utilizing VR in experimental learning models, which emphasize direct experience to foster 21st-century skills such as collaboration, critical thinking, and problem-solving. Thus, ecoethnophysics-based Virtual Reality not only enhances Scientific Literacy but also reinforces the idea that education is rooted in local culture, while opening up space for innovation and global relevance.

# CONCLUSION

The development of ecoethnophysics-based Virtual Reality media within the framework of the Glocal Wisdom model has proven feasible (valid, practical, and effective) in addressing the problem of low connectivity between scientific concepts and the local cultural context, thereby strengthening students' Scientific Literacy. The results of high validity and reliability, high practicality, and high effectivity, confirm that this innovation has proven effective in overcoming the problem of low connectivity between science and local culture. However, time constraints due to student enthusiasm for using VR meant that exploration was not yet fully optimal. Nevertheless, this medium still presents vast opportunities for teachers and researchers to develop experimental and interdisciplinary learning models, so that its use not only strengthens Scientific Literacy but also fosters scientific awareness rooted in local identity while remaining open to global challenges.

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