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# Development of Virtual Reality-Based Ethno-SDGs Learning Media on Colloid Material to Improve Students' Chemical Literacy

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**Keywords**

*Ethno-SDGs, Colloids, Chemical Literacy, Palu Local Wisdom, Virtual Reality*

**Abstract**

This research aims to develop Ethno-SDGs-based learning media integrated with Virtual Reality (VR) technology on the colloid material to improve students' chemical literacy. This media integrates the local wisdom of Palu, such as Kaledo, Kapurung, Palumara, and Utadada, with the chemical concept of colloids. The background of this research is the low chemical literacy of students due to the lack of connection between learning and local contexts and technological innovations. The focus of this research is the development of contextually relevant and technology-based learning media. The research employs a Research and Development (R&D) method with the 4D model (Define, Design, Develop, Disseminate). Data were collected through expert validation of media and content, peer reviews, small-scale trial questionnaires, and pretest and posttest assessments. Expert validation indicated the media's feasibility, with scores of 80% for content aspects and 79% for media aspects, both within the acceptable range. Peer reviews resulted in an approval score of 82% for both content and media aspects. The student responses from the small-scale trial showed a satisfaction rate of 92%, categorized as very feasible. Students also indicated that the media was engaging and helped increase their motivation to learn. The N-Gain test results showed an improvement in chemical literacy skills after using this media. The research concludes that the Ethno-SDGs-based learning media integrated with VR is effective in enhancing students' chemical literacy.

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## INTRODUCTION

In the current era of education, which is shaped by Industry 4.0, the rapid advancement of science and technology is facilitated by the internet and technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and robotics. These technologies play a significant role in advancing the educational landscape. They enable learners to access a vast array of information and learning resources from all over the world, even in areas with limited technological access. However, despite the numerous advantages, Industry 4.0 also presents challenges, one of which is the digital divide that exacerbates educational inequalities, particularly in remote areas. Moreover, this era demands the development of 21st-century skills, one of which is literacy, encompassing the ability to process and comprehend information. This skill is crucial for equipping learners to face the challenges of life (Eliza & Yusmaita, 2021).

Among the various types of literacy, science literacy, which includes chemical literacy, is an essential component of 21st century education. Chemical literacy plays a critical role in helping learners understand fundamental chemical concepts such as the properties of matter, chemical reactions, and their applications in daily life. It is important because, when learners possess strong chemical literacy, they can connect chemistry with the phenomena occurring around them. According to the 2022 Programme for International Student Assessment (PISA) scores, Indonesia ranks low in science literacy, including chemical literacy, posing a significant challenge for the government to improve the quality of education. One of the steps taken by the government to enhance education quality is the development of the Merdeka Curriculum, which provides flexibility for teachers to implement innovative teaching methods that are relevant to the development of teaching media and materials.

The development of chemical learning media that integrates the concepts of Etno-SDGs (Ethno-Sustainable Development Goals) in the topic of colloids is crucial for introduction. The Sustainable Development Goals (SDGs) aim for global education by 2030, which includes education that is relevant to local community needs. One topic that can be integrated with local wisdom is colloids. The research of colloids, which involves dispersion systems, has a strong connection to various daily life phenomena, such as the process of preparing traditional food in Palu. The use of local wisdom in Kaledo, Palumara, and Utadada serves as an example in chemical education that can make learning more profound and meaningful for learners, as they can relate chemistry concepts to their everyday experiences (Sudarmin et al., 2023). In this context, Virtual Reality (VR) technology holds great potential for application in chemistry education as it offers an interactive and engaging learning experience. VR-based media allows learners to explore colloid topics immersively with visualizations that are easier to understand.

The application of VR in learning could address challenges in understanding abstract chemical concepts, such as colloids. Aresearch by Siyamsih (2024) indicates that VR can enhance conceptual understanding and learner engagement, particularly for concepts that are difficult to grasp theoretically. With VR, learners can see and interact with chemical phenomena, such as particle movement, particle interactions, and material structure changes at the submicroscopic level, which are difficult to observe through conventional teaching methods. However, the implementation of VR in education requires adequate technological infrastructure and substantial costs, making it a challenge for schools with limited resources.

In chemistry education, particularly in the topic of colloids, the development of VR-based learning media integrated with Etno-SDG principles is an essential area for research to improve learners' chemical literacy. This research aims to develop VR-based learning media that integrates the concept of colloids with the local wisdom of Palu, especially traditional foods such as Kaledo, Palumara, and Utadada. Thus, chemistry education becomes not only more engaging and relevant to learners but also provides a deeper understanding of how chemistry is applied in their daily lives.

The issues addressed in this research include the low chemical literacy in Indonesia, especially in understanding abstract concepts like colloids. According to a survey conducted among five chemistry teachers in Palu, most teachers face difficulties in explaining abstract colloid concepts, particularly those related to molecular properties and the differences between the dispersed and dispersing phases. The teaching methods used are still dominated by lectures, while the use of interactive and engaging learning media remains limited. This has led to a lack of interest among learners in studying colloids, a crucial topic for improving their understanding of chemistry.

Additionally, the insufficient integration of local wisdom in chemistry education remains a significant problem. The Merdeka Curriculum encourages the integration of local wisdom in the learning process to make education more relevant to learners' daily lives. Therefore, the development of VR-based learning media that incorporates the local wisdom of Palu is crucial to helping learners better understand chemistry concepts, especially colloids, that are relevant to their lives.

The scope of this research includes the development of VR-based learning media integrated with Etno-SDGs

principles in the colloid topic, as well as the evaluation of its effectiveness in enhancing chemical literacy. The research will also explore how the local wisdom of Palu, such as traditional foods like Kaledo, Palumara, and Utadada, can be integrated into chemistry education to provide a real-world context that helps students better understand colloid material. Furthermore, this research will evaluate how this VR-based learning media can be applied within the Merdeka Curriculum, which emphasizes the importance of project-based and exploratory learning.

The research questions posed in this research focus on three main issues: first, what are the stages in the development of VR-based learning media integrated with Etno-SDGs for the colloid topic? Second, how valid and feasible is the VR-based learning media in the context of colloid material? Third, what is the effect of VR-based learning media on improving learners' chemical literacy? The goal of this research is to produce VR-based learning media integrated with Etno-SDGs principles and the local wisdom of Palu, and to assess the effectiveness of this learning media in improving chemical literacy among students.

The practical and theoretical benefits of this research are expected to be significant. Theoretically, this research aims to enrich scientific knowledge regarding the development of VR-based learning media that integrates Etno-SDGs principles in chemistry, and to expand the academic references on interactive teaching strategies that can enhance chemical literacy. Practically, this research is expected to provide direct benefits to students, teachers, and educational institutions. For students, it provides contextual and interactive learning media that can improve their understanding of colloid material and chemical literacy. For teachers, the VR-based learning media serves as a tool to teach difficult chemical concepts more engagingly and effectively. For educational institutions, this research can serve as a reference for developing technology-based learning policies that support the achievement of students' competencies in accordance with the demands of the Merdeka Curriculum.

The product generated from this research is VR-based learning media integrated with the Etno-SDGs learning model for colloid topics. The primary product developed includes a VR application that provides interactive visualizations of colloid concepts integrated with the local wisdom of Palu, such as traditional foods from the region. Additionally, the research will produce teaching modules focused on colloid learning that integrate Palu's local wisdom, as well as teaching materials explaining the relationship between chemistry and local culture and its impact on environmental sustainability and health. Chemistry literacy questions will also be developed to assess students' understanding of colloid concepts in real-life contexts.

However, this research also includes several assumptions and limitations. One of the main assumptions is that students and schools have access to VR devices and supporting technology. Additionally, students' acceptance of VR technology and the integration of local wisdom in learning presents a challenge, as there is variability in students' comfort levels and adaptability to this technology. Therefore, it is important to assess students' acceptance of this approach during the learning process.

## METHODS

### Type of Research

This research employs a Research and Development (R&D) design, with the primary goal of developing a product and testing its effectiveness. The research design follows the 4D model, which includes four systematic stages: Define, Design, Development, and Dissemination. This framework is particularly chosen for its structured and iterative process in creating Etno-SDGs-based Virtual Reality (VR) learning media aimed at improving students' chemical literacy. The study uses a mixed-methods approach, where quantitative methods are employed to assess the effectiveness of the developed learning media, and qualitative methods are used to explore the experiences and perceptions of both students and teachers. These qualitative insights are gathered through observations and interviews, providing a comprehensive understanding of how the media is perceived and applied in real-world classroom settings.

### Research Design and Procedure

The research design strictly adheres to the 4D model, ensuring a step-by-step approach to the development of innovative learning media. The research is conducted at SMAS GKST Imanuel Palu, located in Palu City, Central Sulawesi. Each stage of the 4D model is scheduled over a four-month timeline: Define (August 2024), Design (September 2024), Development (October 2024), and Dissemination (November 2024), as described in the figure below:

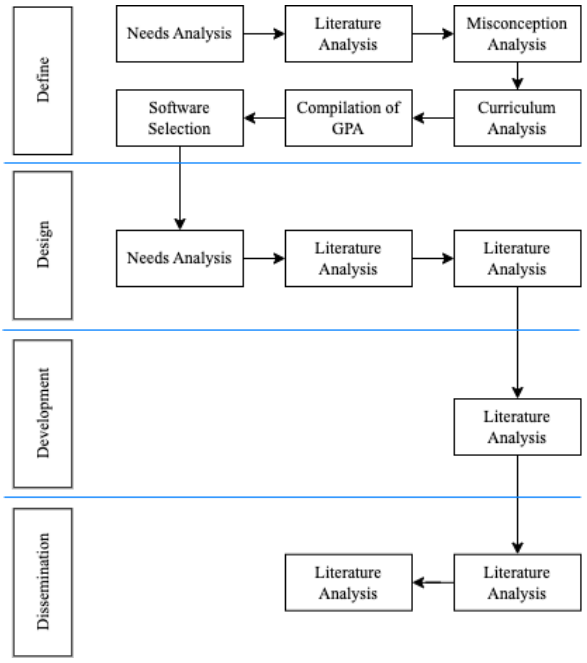


Figure 1. Research Procedure

In the Define stage, the researcher conducts a thorough needs analysis to identify specific learning challenges, reviews relevant literature, and analyzes the curriculum to ensure alignment with competency achievement indicators (IPK). These indicators are further customized to integrate elements of local wisdom from Palu, reflecting the ethos of Etno-SDGs. The Design stage focuses on creating the conceptual foundation of the VR learning media. This includes the development of a storyline, user instructions, and learning scenarios that are informed by prior research findings and pedagogical theories. The design is then translated into a prototype for further refinement. During the Development stage, the prototype undergoes validation by chemistry experts, media experts, and university students. This process ensures that the content is accurate, the media is visually appealing, and the overall usability aligns with educational standards. Feedback from these stakeholders is then incorporated into the final version of the product. And last, the Dissemination stage involves implementing the VR learning media in real classroom settings. Students participate in this phase, where their feedback is collected through questionnaires, chemical literacy tests, interviews, and observations. The testing process aims to evaluate the practical application of the media and its impact on learning outcomes.

**Data Sources and Research Subjects**

This research collects both quantitative and qualitative data to provide a holistic understanding of the learning media's impact. Quantitative data are derived from pre-test and post-test assessments designed to measure students' chemical literacy in the context of colloid material. These tests provide numerical evidence of the media's effectiveness. Meanwhile, qualitative data are collected through questionnaires distributed to students. These aim to capture students' perceptions of the learning process, particularly their views on the integration of Palu's local wisdom within the curriculum and their responses to the VR-based learning media. The research subjects include 20 eleventh-grade students from SMAS GKST Imanuel Palu, who are selected to represent the target audience for the developed media.

**Research Instrumentation**

The research employs multiple instruments to ensure accurate and comprehensive data collection. Questionnaires are used to gather perceptions from teachers, experts, peers, university students, and students regarding the learning media's usability, relevance, and impact. Validation sheets are designed for experts

and peers to assess the feasibility and content quality of the media. These sheets serve as a critical tool for refining the product.Chemical literacy tests are administered to measure students' understanding of colloid concepts both before and after interacting with the VR media. These tests evaluate the improvement in students' knowledge and provide quantitative data for analysis. Additionally, media review sheets are utilized by university students to evaluate the quality of the content, as well as the design and usability of the VR learning media

**Research Instrumentation**

The data analysis process combines various methods to evaluate the effectiveness and feasibility of the VR learning media. Media feasibility is analyzed using a 1-5 scale to calculate validation percentages, applying the formula below:

$$\text{Presentase Validation} = \left(\frac{Total\ Score\ Obtained}{Maximum\ Score}\right) x\ 100\%$$

The total score is the sum of all indicators provided by the expert lecturers, while the maximum score is calculated by multiplying the number of indicators by the highest value on the scale (for example, 5). The validation precentage (%) indicates the extent to which the media or content meets the expected standards. The results will be analyzed using the feasibility criteria in the table below:

Tabel 3.1 Eligibility Criteria

| Criteria | Percentage (%) |
|---|---|
| Tidak Valid | 0% - 20% |
| Kurang Valid | 21% - 40% |
| Cukup Valid | 41% - 60% |
| Valid | 61% - 80% |
| Sangat Valid | 81% - 100% |

Source: Sugiyono, 2016

An analysis will also be conducted on the student response questionnaires to assess the validity of the Etno-SDGs-based VR learning media by calculating the average score of chemical literacy and evaluating the student responses to the Etno-SDGs learning media. The results will then be analyzed based on response criteria similar to those presented in Table 3.1. And last, this research will also analyze the students' chemical literacy outcomes using the N-Gain formula to calculate the improvement in students' scores after the learning process, as presented in the equation below

$$\text{N-gain} = \frac{posttest\ score - pretest\ score}{ideal\ score - pretest\ score}$$

In this case, the N-Gain (G) is calculated by comparing the post-test and pre-test scores, using the maximum score as a reference. After calculating the N-Gain for each participant, the next step is to determine the average N-Gain for all students. This average is then interpreted based on the categories outlined by Hake (1999) to assess the level of improvement in learning outcomes. The results of the calculation are presented in Table 2 below:

Tabel 3.2 Gain-Value Interpretation Criteria

| N-gain Value | Category |
|---|---|
| $g > 0,7$ | High |
| $0,3 \leq g \leq 0,7$ | Medium |
| $g<0,3$ | Low |

Source: Hake, 1999

Therefore, this research method is designed to provide in-depth insights into the development and implementation of Etno-SDGs-based Virtual Reality learning media for enhancing students' chemical literacy. Through a systematic approach, from the design phase to dissemination, along with comprehensive data analysis, it is expected that this research will make a significant contribution to the development of more relevant and innovative chemistry education, particularly in the field of education.

## RESULTS AND DISCUSSION

This teaching module is designed to introduce the concept of colloids through a local wisdom-based approach from the city of Palu, integrating chemistry learning into traditional foods such as Kaledo, Kapurung, Palumara, and Utadada. Kaledo, a signature bone marrow soup from Palu, involves colloidal principles in its spice-rich broth, with dispersed particles that contribute to its unique flavor. Palumara, a spiced fish soup, demonstrates the phenomenon of adsorption, where spice particles adhere to the fish surface, enhancing flavor complexity. Uta Dada, a spiced fish dish with a thick broth, reflects colloidal stability influenced by ionic interactions from ingredients such as salt and spices. This module covers the definition, classification, properties, and applications of colloids, as well as their relevance in the preparation and characteristics of these traditional foods..

(a) (b) (c) (d)

Figure 2. (a) Kaledo, (b) Palumara, (c) Kapurung, (d) Utadada

Through a Problem-Based Learning (PBL) approach and the use of Virtual Reality (VR) technology, students can interactively understand phenomena such as the Tyndall effect, adsorption, and coagulation. This module also promotes cultural values and sustainability by linking learning to the principles of Ethno-SDGs. Students are encouraged to identify the role of colloids in the texture and broth of traditional dishes, as well as to explore eco-friendly innovations that can be applied in the processing of local foods in Palu..

The development of Ethno-SDGs-based Virtual Reality (VR) learning media aims to enhance chemical literacy on the concept of colloids by integrating local aspects and technology. The first stage, Define, begins with an observation at SMAS GKST Imanuel Palu, which revealed teachers' difficulties in teaching the abstract concept of colloids. Based on this finding, more interactive and locally relevant VR-based media were developed. In the Design phase, a flowchart and storyboard were prepared, depicting the colloid content through typical foods of Palu, such as Kaledo and Kapurung, within 11 virtual gallery rooms. The Development stage involved validation and revisions based on reviewer feedback, particularly in visualizing colloid concepts and submicroscopic animations. In the Dissemination phase, media trials were conducted to evaluate both its technical feasibility and effectiveness.

Figure 3, Learning Process

The results of the media development indicate that the Ethno-SDGs-based VR learning media effectively presents the colloid concept in a more engaging and comprehensible manner. By using 3D objects, videos, and interactive simulations, students are able to understand properties of colloids, such as the Tyndall effect,

Brownian motion, and adsorption, which were previously difficult to explain conventionally. Moreover, the integration of local culture, such as typical Palu foods, provides relevant context, making the learning experience more contextual and appealing to students. This media has also proven to enhance motivation and facilitate a better understanding of the connection between chemical theory and its real-world applications. According to student feedback, the media is considered effective in increasing engagement, simplifying the understanding of complex concepts, and promoting more active and enjoyable learning.

Furthermore, the feasibility of the Ethno-SDGs-based Virtual Reality (VR) learning media developed for Colloid material has been validated through several validation stages, namely validation by lecturers, college students, and colleagues.

Gambar 4. Validation Process

The first validation was conducted by a subject matter expert who assessed two main aspects is it content and media. The content validation showed that the media received an approval rating of 80%, indicating that most of the presented material was relevant and accurate. However, several suggestions were made to clarify the material flow and provide more detailed explanations of certain colloidal concepts, particularly related to submicroscopic representations. This was deemed important to enhance students' understanding of concepts that cannot be observed with the naked eye. Regarding the media aspect, the score obtained was 79%, indicating that the media is fairly effective in terms of design and information delivery. Feedback from the expert included suggestions to adjust the color balance to make it more appealing and not distract students' focus, as well as recommendations to improve the clarity of the 3D objects used in the media to enhance visual quality and readability.

Subsequent validation was conducted by peers with experience in using technology-based learning media. At this stage, the media received scores of 82% for both the content and media aspects, indicating that peers also deemed the media appropriate for use with minor improvements. Suggestions from peers included adding more varied interactive elements, such as simulations or quizzes, to increase student engagement. There were also recommendations to make the virtual objects more consistent and easier to understand during the learning process.

After the validation process by experts and peers, the media was tested by graduate students, who reviewed its effectiveness and relevance. The majority of the students provided positive feedback on the inclusion of local wisdom from Palu, such as Kaledo (a traditional Palu beef soup) and Palumara (a traditional drink), as part of the learning content. They felt that incorporating these local elements provided a more relevant and engaging context for learning the colloid material. However, some students suggested a more detailed explanation of the relationship between submicroscopic concepts and their application in traditional foods to help students better understand the connection. The average scores given by graduate students for the media were very high, ranging from 9.8 to 9.9 out of 10, indicating that the media was well-received and deemed effective in delivering the material in an engaging and interactive way.

Moreover, based on the results of the student response questionnaire regarding the use of Ethno VR learning media for the colloid concept, it can be concluded that the media received very positive feedback. The media's appearance aspect showed that 92.5% of students found the VR media design appealing and in line with the learning theme, while 92.5% felt that the media layout was easy to understand. Illustrations and images in the VR media were considered supportive of material comprehension by 89%, and 90% of students felt that the visual display was very clear and relevant. 86% found the media easy to navigate without technical issues, and 97.5% stated that the media's features worked well. Regarding the content aspect, 94% of students felt that the material presented was in line with the learning objectives, 94% felt that the explanations covered important colloid concepts, and 85% found the material easy to understand. The language used was considered

clear and simple by 89%, and 94% of students felt that the media integrated the colloid concept with local Palu foods in a relevant manner, while 95% felt that the examples of local foods helped in understanding the colloid concept. In the interactivity aspect, 94% of students felt that the media provided an interactive learning experience, 98% felt that the activities in the media made learning more engaging, and 86% felt more involved in the learning process. 85% felt that the VR media increased their curiosity about the material. Finally, in terms of comprehension and motivation, 92% felt that the media helped them understand the colloid material, 94% felt that the media explanation boosted their confidence, 90% felt more motivated to study chemistry, and 92% expressed interest in using VR media for other chemistry topics. Overall, the average approval rating for each aspect ranged from 90% to 97.5%, indicating that this VR learning media is highly effective and favoured by students in supporting learning while improving their understanding and motivation.

Last, this study also tested the impact of VR-based learning media, incorporating local wisdom from Palu, on students' chemical literacy by comparing pretest and posttest scores. The tests were conducted for both the control and experimental classes, each with 30 questions about the chemical literacy of the colloid concept, which were converted to a scale of 1-100. The pretest and posttest scores for both the control and experimental classes are presented in Figures 1 and 2 below:

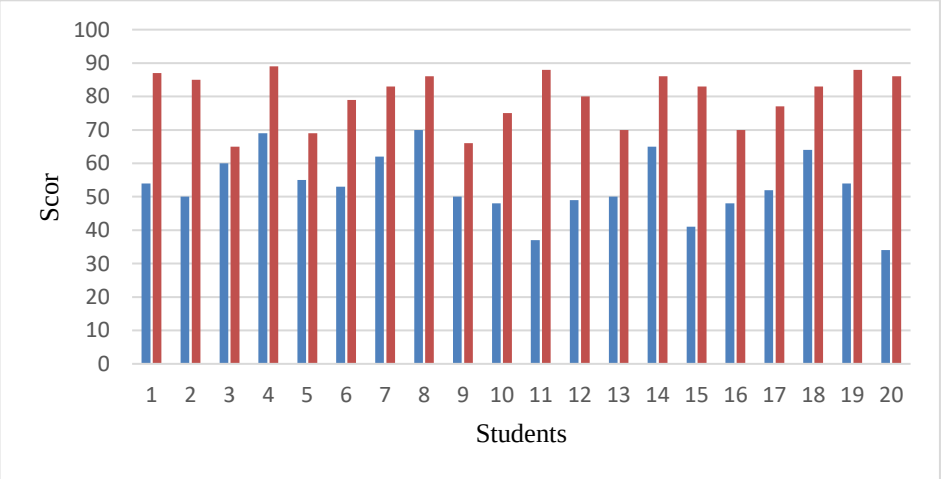


Figure 1 Pre-test and Post-test Score Graph of Control Class

In the control class, the research findings indicate that students' chemical literacy abilities showed improvement, despite still utilizing conventional teaching methods such as lectures and group discussions. The average pretest score in the control class was 53.5, while the average posttest score reached 79.5. Although the control class integrated local wisdom, such as the application of the colloid concept in typical foods from Palu, students still struggled to grasp the colloid concept correctly. Of the 20 students in the control class, the N-Gain scores revealed that one student showed a low improvement in chemical literacy, 13 students exhibited moderate improvement, and 6 students demonstrated high improvement. This suggests that while there was improvement, conventional teaching methods were not sufficiently effective in fostering a deep understanding of chemical concepts among the students.

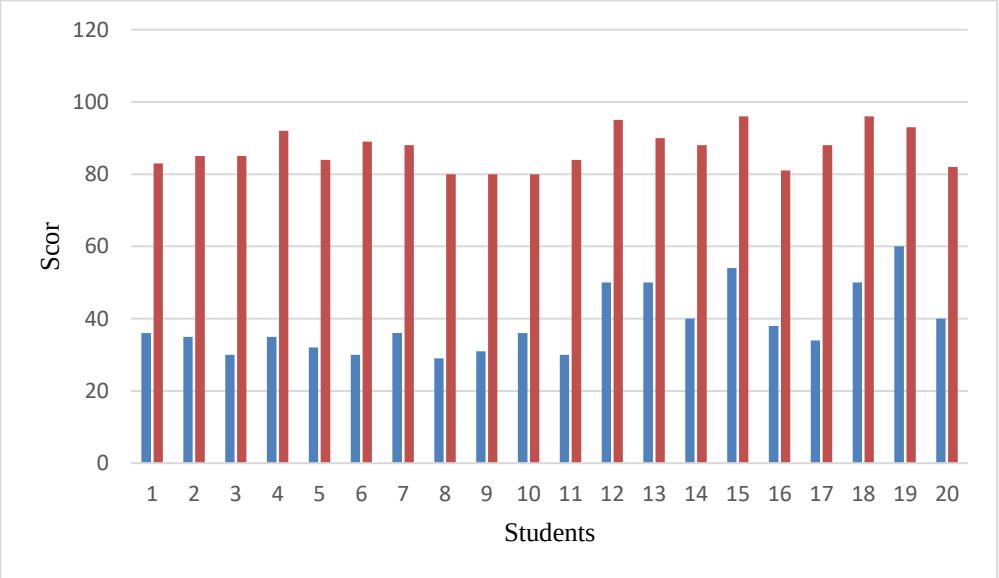


Figure 2 Pre-test and Post-test Score Graph of Experimental Class

In contrast, in the experimental class, as shown in Figure 2, which utilized Ethno-SDGs-based Virtual Reality (VR) learning media, the research results showed a more significant improvement in students' chemical literacy abilities. The average pre-test score in the experimental class was 38.8, while the average post-test score reached 87. The use of VR media integrated with local wisdom allowed students to experience a more interactive and enjoyable learning environment. VR-based learning provided students with the opportunity to learn as if they were in a real-life situation, thus enhancing their engagement with the subject matter. Of the 20 students in the experimental class, 2 students showed moderate improvement in chemical literacy, while 18 students demonstrated significant improvement, with high gains. The N-Gain values in the experimental class indicate that VR media was more effective in improving students' chemical literacy compared to conventional methods. The immersive and active learning experience in the experimental class proved to have a significantly positive impact on students' understanding of the colloid concept.

## CONCLUSION

Based on the results of the development research on the Ethno-SDGs-based Virtual Reality (VR) learning media for the colloid concept, it can be concluded that this media was developed using the Research and Development (R&D) method with the 4D model (Define, Design, Development, Dissemination). The media is presented in the form of a museum with 11 gallery rooms that showcase typical foods from Palu related to the colloid concept. The use of this VR media has proven to be effective in improving students' chemical literacy, particularly in the experimental class, which showed significant improvement compared to the control class. The feasibility test results indicate that this media is suitable for use, receiving positive evaluations from experts, peers, graduate students, and students, although several suggestions for improvement were made, such as adding visual elements and interactive features.

Based on these findings, it is recommended that educators utilize this VR media as an effective alternative learning tool to enhance students' chemical literacy. Additionally, other researchers are encouraged to develop Ethno-SDGs-based VR learning media for other chemistry concepts to further enhance students' motivation and learning experiences. This assessment instrument can also be adopted for developing tools to evaluate other aspects of the IPAS Project.

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