

# Integrating ethno-VR wedhang uwuh into an inquiry project learning model to actualize science and technology literacy in accordance with sustainable development goal 4

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**Abstract.** Science and technology literacy among Indonesian students remains low, limiting their engagement with Sustainable Development Goal (SDG) 4 on quality education. This study aimed to develop Ethno-Virtual Reality (Ethno-VR) learning media based on the Wedhang Uwuh Spice Museum to enhance students' literacy while integrating cultural knowledge and local wisdom. Using a research and development approach, data were collected through case studies, observations, interviews, and literature review to explore sociocultural, economic, health, and educational aspects of Wedhang Uwuh, informing the design of interactive content, including virtual museum tours, organoleptic tests, phytochemical analysis, structural observations, and aroma profiling, enriched with multimedia learning materials. The Ethno-VR media successfully created a valid, engaging, and contextually rich virtual learning environment, and students responded positively, finding it innovative and effective in improving their science and technology literacy. Based on the results of the research and discussion, it can be concluded that (1) an integrated pattern of IPjLM and Ethno-SSI has been identified in the form of an integrated model; (2) the development of the Ethno-VR Wedhang Uwuh media successfully produced a valid, attractive, and contextually rich virtual learning environment that integrates scientific, cultural, and health perspectives along with experimental explorations; (3) students responded positively to the media, finding it engaging, innovative, and effective in enhancing their science and technology literacy; and (4) these findings indicate that the Ethno-VR media contributes to achieving Sustainable Development Goal 4 by supporting inclusive, equitable, and quality education.

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## 1 Introduction

Improving science and technology literacy has become a key priority in achieving the *Sustainable Development Goals* (SDGs), particularly in the area of quality education (SDG 4) [1]. However, science and technology literacy levels, which serve as indicators of educational quality across different levels of education in Indonesia, remain relatively low in both conceptual understanding and real-world application [2]. Students' limited abilities in critical thinking, problem solving, and understanding the interconnections among science, technology, and sociocultural contexts indicate a significant problem that current teaching practices are often still theoretical and insufficiently contextual, frequently failing to foster the competencies needed for scientifically aware individuals who can apply knowledge in everyday life [3]. This disconnect undermines the targets of SDG 4 because students are not adequately equipped with the science and technology literacies essential to the 21st century.

While Virtual Reality (VR) has shown promise in enhancing engagement, most educational VR content remains culturally generic. There is a significant gap in research regarding how Ethno-Virtual Reality (Ethno-VR), which integrates indigenous wisdom with immersive technology, can facilitate Socioscientific Issues (SSI)-based learning. This research addresses this by developing a platform centered on Wedhang Uwuh, a traditional beverage recognized as National Intangible Cultural Heritage

Wedhang Uwuh is made from a blend of spices such as ginger, sappan wood, cloves, cinnamon, nutmeg leaves, and lemongrass, reflecting profound local wisdom and cultural heritage in the region [4], [5]. The rich combination of spices in Wedhang Uwuh contains various bioactive phenolic compounds, including gingerol, zingerone, shogaol, eugenol, and brazilin, that contribute not only to its distinctive flavor but also to its potent antioxidant properties [6]. Wedhang Uwuh is not merely a cultural artifact; it is a complex chemical system. The extraction of bioactive compounds such as gingerol, eugenol, and brazilin offers a rich medium for teaching chemical concepts like diffusion, oxidation, and thermal-chemical reactions [7]. The novelty of this study lies in its transdisciplinary pedagogical framework. Unlike standard VR simulations, Ethno-VR uses the "Integrated Pattern" to merge the Inquiry Project Learning Model (IPjLM) with local cultural narratives. This provides a unique "Ethno-SSI" lens where students don't just learn chemistry; they evaluate the social, ethical, and health-related pros and cons of traditional practices through modern scientific data.

The aims of this research are: (1) to identify the integration pattern between the project-based inquiry learning model and the Ethno-SSI approach in the context of Wedhang Uwuh; (2) to explore and elaborate the pros and cons of Wedhang Uwuh based on Ethno-SSI; (3) to design and develop student worksheets and Ethno-VR Wedhang Uwuh learning media; (4) to implement the IPjLM model based on Ethno-SSI supported by Ethno-VR Wedhang Uwuh to improve science and technology literacy; and (5) to determine students' responses to the implementation of the IPjLM model with Ethno-VR media. The primary innovation of this research lies in the development of Ethno-VR learning media. This technology-based tool uses Virtual Reality (VR) to introduce and preserve local culture related to Wedhang Uwuh, a traditional Indonesian herbal beverage composed of various spices that reflects rich cultural heritage and is recognized for its historical background and health-related properties, including antioxidant and antimicrobial benefits.

## 2 Method

### 2.1 Research Method

This research used a Research and Development (R&D) approach to develop Ethno–Virtual Reality (Ethno-VR) learning media grounded in the local wisdom of Wedhang Uwuh for science education, aligned with *Sustainable Development Goal 4* on quality education. The research involved subject-matter experts in science education, ethnoscience, and educational technology as validators, and 60 preservice science teachers as media users. Data collection instruments included expert validation sheets and practicality questionnaires. Additional data were gathered through observations, interviews, and documentation.

### 2.2 Research Instruments

Data were collected using: (1) questionnaires and evaluation rubrics to assess the instructional products and Ethno-VR Wedhang Uwuh learning media developed by student groups; (2) student response questionnaires using a Likert scale to measure interest, motivation, and perceptions of VR use and cultural relevance; and (3) classroom observation sheets to document student engagement and learning processes.

### 2.3 Experimental Procedure for Phytochemical and Organoleptic Testing

Finely ground Wedhang Uwuh powder is weighed and extracted with a solvent, such as 70% ethanol, by reflux or maceration. The filtrate is collected as the Wedhang Uwuh extract for further testing. Phytochemical tests detect bioactive compounds including alkaloids (Dragendorff and Mayer reagents), flavonoids (Shinoda test with magnesium and HCl), saponins (shaking with hot water), and steroids and terpenoids (Liebermann-Burchard reagent). Organoleptic evaluation is conducted by at least three panelists, who assess aroma, taste, color, and texture on a 1–5 scale. Volatile compounds are analyzed using an Arduino-based gas sensor with the extract or its vapor in a closed test chamber. All data are recorded, and results from phytochemical, organoleptic, and volatile compound tests are combined to provide a complete profile of the Wedhang Uwuh extract.

### 2.4 Development Procedure of Ethno-VR Wedhang Uwuh Media

The development of the Ethno-VR Wedhang Uwuh media followed a systematic Research and Development (R&D) steps, utilizing a modified Borg & Gall model adapted into four phases. Four main stages were implemented: (1) Preliminary Research; including needs analysis, literature review, and exploration of Wedhang Uwuh's scientific and cultural values; (2) Product Design, where storyboards, visuals, and content were created to integrate ethnoscience, technology, and socioscientific issues; (3) Development and Validation, where the media was built using spatial application software and validated by experts for accuracy, cultural appropriateness, and educational quality; and (4) Testing and Revision, where preservice science teachers trialed the media to assess practicality and effectiveness, with revisions made based on their feedback.

A spatial framework was then established with four themed galleries: Science, Health, Structure, and Art, into which designed and collected content was systematically integrated. Each gallery was reviewed for completeness before producing a guided video tour for broader dissemination and engagement. The final Ethno-VR Wedhang Uwuh media was

comprehensively evaluated for educational quality, coherence, and learning impact. This structured, interactive process ensured that the media not only met technical and pedagogical standards but also respectfully preserved and reflected the cultural richness of Wedhang Uwuh.

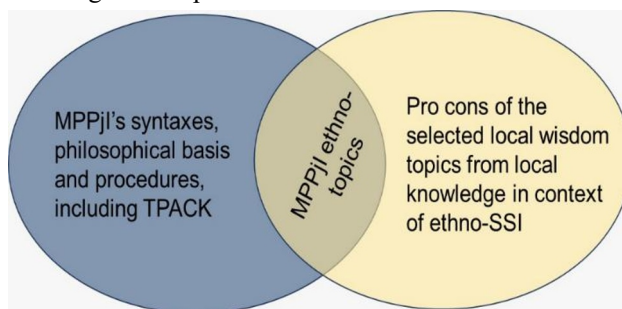
## 2.5 Data Analysis

Data analysis followed a descriptive-analytical approach for Research and Development (R&D). Quantitative data from expert validation and student practicality rubrics were analyzed using descriptive statistics (percentages and mean scores) to determine the media's feasibility. Concurrently, qualitative data from observations and interviews were analyzed using thematic analysis. This allowed for a comprehensive evaluation of the 'Ethno-SSI' framework, ensuring the final Ethno-VR product was both scientifically accurate. Methodological triangulation was achieved by cross-referencing expert scores with student feedback to refine the media's final iteration.

## 3 Result and Discussion

### 3.1 Integrating the IPjLM with Ethno-SSI

The first objective of this research is to identify the integration pattern between the Inquiry Project Learning Model (IPjLM), Ethno-SSI, and Ethno-VR media. Therefore, this study analyzed various learning resources related to integration models in science learning. Based on the diversity of these models, this research determined that the integration of IPjLM and Ethno-SSI constitutes an integrated model, which is a learning approach that deliberately connects multiple aspects both within a single subject and across different topics, while maintaining the same core topic, enabling students to gain a complete and meaningful learning experience and improve their science and technology literacy [8], [9]. Figure 1, as a result of this research, illustrates how IPjLM and Ethno-SSI, along with Ethno-VR, are systematically connected with the ethno-science approach and socioscientific issues (SSI) through Virtual Reality (VR), serving as a mediation tool to support science literacy, cultural awareness, and technological competencies.



**Fig. 1.** Integrated Pattern of the Ethno-SSI with IPjLM and Virtual Reality

### 3.2 Phytochemical and Organoleptic Test Results

The research results indicate significant physical and sensory changes in Wedang Uwuh samples before and after reflux (Table 1). Prior to reflux, the dry sample appeared as a fine brown powder with a pungent aroma and a spicy-sweet taste profile. After reflux, the sample

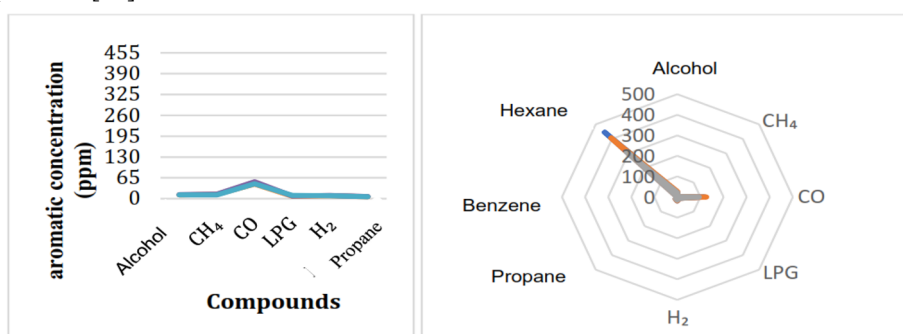
transformed into an orange-colored liquid with a pungent aroma, blended with ethanol, and a taste profile dominated by bitterness, while retaining spiciness. These changes in color, flavor, and aroma reflect the extraction of soluble compounds and the modification of volatile constituents resulting from high temperatures and thermal reactions during the reflux process. Volatile compounds such as terpenoids, alcohols, aldehydes, and ketones, which are secondary metabolites of plant materials, contribute significantly to the characteristic aroma of spices and are commonly identified using Gas Chromatography–Mass Spectrometry (GC-MS) techniques [10].

The use of organic solvents with low alcohol content in this study indicates that the drying and brewing processes of Wedang Uwuh do not generate significant amounts of alcohol. Potentially hazardous aromatic compounds, such as benzene and hexane, were detected only at very low concentrations, confirming that the distinctive aroma of Wedang Uwuh primarily originates from natural volatile compounds present in spices such as red ginger, sappanwood, and other herbal ingredients [11]. These findings are important for fostering science and technology literacy among chemistry education students, as the quantitative characterization of aroma composition provides a foundation for developing gas-sensor-based aroma analysis methods and interactive learning media that connect volatile compound data with empirical experience [12].

**Table 1.** Organoleptic Test of Products from Wedhang Uwuh

Observation	Before reflux (dry)	After Reflux (wet/liquid)
Color	Brown,	Orange
Shape	Fine powder after softening	Liquid
Aroma	Pungent with various odors	Pungent and mixed with the smell of ethanol
Taste	Spicy and sweet	Bitter and spicy

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**Fig. 2.** Results of Organoleptic Tests of Dry and Wet Wedang Uwuh and Analysis of Volatile Compounds of Wedang Uwuh using an Arduino Gas Sensor

Based on the presented graphical data, the volatile compound profile of the sample indicates that LPG, Hexane, and Alcohol are the predominant contributors to the detected aroma. LPG exhibits the highest concentration in the line chart, whereas Hexane and Alcohol reach peak values in the radar chart, underscoring their significant role in defining the sample's aromatic characteristics. Other compounds, including CH<sub>4</sub>, H<sub>2</sub>, Propane, CO, and Benzene, are present at comparatively low concentrations and exert minimal influence on the overall aroma. These results suggest that the sample's volatility is primarily driven by light hydrocarbons and alcohol, with negligible contributions from other gaseous compounds. Such findings are critical for quantitatively characterizing aroma composition and have potential applications in gas-sensor-based aroma analysis or in the development of interactive educational media that link aromatic data with empirical experience.

This study differs from previous research in that the analysis of volatile compounds in the aroma of Wedhang Uwuh was conducted using data obtained from trapping and analysis with Arduino-based gas sensors. In contrast, earlier studies primarily employed Gas Chromatography–Mass Spectrometry (GC-MS) to analyze volatile compounds in spices and herbs. For instance, the analysis of red ginger identified volatile constituents such as zimenene, borneol, geraniol, and linalool. The dominant volatile components are known to vary across species and analytical conditions, reflecting the chemical diversity present in plant extracts. Similar analyses on coffee have revealed multiple groups of volatile compounds that collectively define the overall aroma profile. Accordingly, the volatile profile of Wedhang Uwuh can be interpreted as a consequence of volatilization and thermal chemical reactions of complex organic compounds that occur during the heating and preparation of its herbal ingredients.

The use of gas sensors in volatile analysis offers a low-cost, rapid, and non-destructive alternative for aroma assessment. The sensors employed in this research can be further developed into a sensor array system (electronic nose) capable of capturing complex aroma patterns in food products and spices. Although the sensitivity and specificity of these sensors are still lower than those of advanced analytical techniques such as GC–MS, their integration with multivariate statistical analysis and machine learning has been shown to significantly enhance the accuracy of detecting and classifying volatile organic compounds in food and spices. Nevertheless, further investigation using more precise analytical instruments, such as GC–MS, is required to identify individual aroma compounds in greater detail.

### **3.2 Interview Results with Source Narrator Regarding Wedhang Uwuh**

The implementation of the Ethno-VR media was accompanied by qualitative interviews with students enrolled in the mini-research course to evaluate their ability to navigate socioscientific issues (SSI) related to traditional medicine. When queried about the efficacy of Wedhang Uwuh in boosting the immune system, students demonstrated an ability to link traditional practices with biochemical principles. They noted that the diverse spice blend contains essential bioactive compounds, particularly antioxidants, which contribute to immunological support. Critically, students also displayed nuanced reasoning by clarifying that while these herbal beverages provide functional health benefits, they should complement rather than replace medical treatments and a healthy lifestyle.

Furthermore, the interviews explored the potential risks of excessive consumption to assess the students' understanding of dosage and physiological impact. Participants correctly identified that improper portions of Wedhang Uwuh could lead to adverse side effects, such as gastric irritation from high ginger concentrations or blood pressure fluctuations linked to excessive cinnamon intake. This ability to evaluate both the benefits and the "pros and cons" of traditional consumption reflects a sophisticated level of scientific literacy. By integrating

laboratory evidence, such as the presence of anti-inflammatory and antimicrobial compounds, with a cautious approach to health risks and medication interactions, the students showcased the transdisciplinary thinking that the Ethno-VR and IPjLM framework aims to cultivate.

### 3.3 Ethno-VR Media Development Results for the Wedhang Uwuh Topic

In developing the Ethno-VR media for the Wedhang Uwuh Museum, the following activities were carried out: (1) planning the content and assets to be presented in the gallery space within the Virtual Reality space; (2) implementing the prepared assets and content into the gallery space within the Virtual Reality space; and (3) testing the Ethno-VR media product to ensure it could be operated and executed correctly. The following section presents the sequence of content and context for the Ethno-VR media at the Wedhang Uwuh Museum, as presented in Table 2.

**Table 2.** Content and Context Presentation of the Wedhang Uwuh Museum's

Ethno-VR Media		
No	Virtual Gallery Space	Description of Content and Assets
1	Introductory Section	Provides an overview of the Wedhang Uwuh Spice VR Museum, including the UNNES symbol, notable leaders, student contributors, and museum content. Includes an introductory presentation and the 'Wedhang Uwuh' song.
2	First Floor Gallery	Presents scientific literacy on the history and diversity of Wedhang Uwuh, objectives of ethno-VR research, public and expert perspectives on its benefits and risks, the preparation process, religious insights, a prayer room, and a Wedhang Uwuh stall.
3	Second Floor Gallery	Features technological literacy, traditional preparation methods, health benefits, and brewing processes of Wedhang Uwuh. Concludes with videos, songs, documentaries, and research presentations related to Wedhang Uwuh.
4	Closing Gallery	Contains a library with reference materials and practical activity documents, including videos, posters, LKM books, and journal articles related to Wedhang Uwuh.

The development of the Wedhang Uwuh Ethno-VR museum represents an innovative educational medium that integrates cultural heritage with immersive Virtual Reality learning technology. This Ethno-VR platform not only preserves the ethnocultural narrative of Wedhang Uwuh but also enhances accessibility and engagement for students and the broader public by providing an interactive, immersive museum experience that transcends physical and geographic boundaries. Previous studies have shown that the use of virtual reality in virtual museum contexts can increase student engagement, motivation, and cognitive presence, making cultural and scientific literacy more engaging and memorable. Furthermore, Ethno-VR enables experiential learning by intuitively linking empirical data with cultural narratives, supporting cultural, scientific, and technological literacy among chemistry education students. The product of the Ethno-VR media for Wedhang Uwuh, resulting from this development, is presented in the in Figure 3. Meanwhile, the validation results for the Ethno-VR media on the topic of wedhang, as assessed by experts, are presented in Table 3.



**Fig. 3.** Virtual gallery feature screen on the first Floor.

**Table 3.** Ethno-VR Validation Results for Wedhang Uwuh Development

No	Component	Average Score	Achievement Level
1	Visual display	3.75	Excellent
2	Audio quality (sound, effects, clarity)	3.25	Good
3	Clarity of text and instructions	2.80	Fair
4	Relevance of material to learning objectives (SDGs 4)	3.50	Good
5	Accuracy and reliability of information	3.75	Very Good
6	Clarity of concept delivery	3.75	Very Good
7	Media appeal	3.50	Good
8	Ease of understanding material	3.75	Very Good
9	Supporting media	4.00	Excellent
10	Provides insights into the SDGs	4.00	Very Relevant
11	Usability and flexibility of media	4.00	Very Flexible
12	Experiential learning opportunities	3.50	Good
Average		3.80	

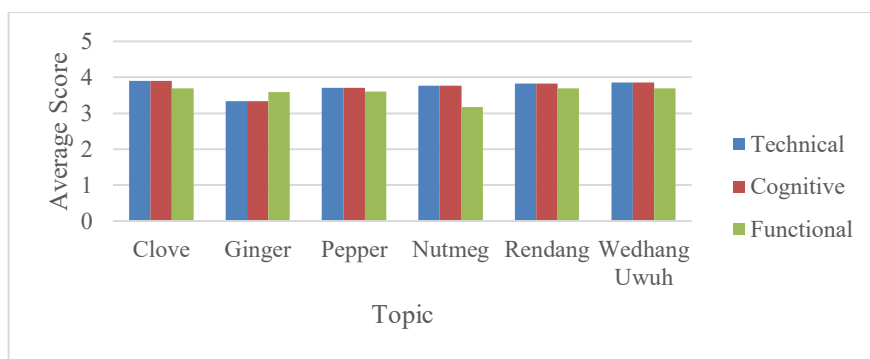
Based on the validation results of the Ethno-VR media that have been developed, the media obtained an average score of 3,80 means that the Ethno-VR spice media is suitable for use in collecting data on the Influence of Ethno-VR media implementation on SDGs literacy in the field of quality education, particularly in the components of students' scientific and technological literacy. Watching this virtual gallery video can enhance students' understanding of science and local wisdom related to *wedhang uwuh*. In the Ethno-VR gallery, several interview videos with *wedhang uwuh* practitioners provide additional insight into the drinking culture and its pros and cons, inspiring students to adopt healthier, more environmentally friendly *wedhang uwuh* consumption habits, such as moderate intake.

### 3.4 Implementation of Integrated Ethno-SSI and IPjLM

In this research, the IPjLM Ethno-SSI approach supported by the Wedhang Uwuh museum was implemented to develop students' scientific and technological literacy, as well as inquiry skills such as observing, questioning, experimenting, associating, and communicating. The core concept of IPjLM was integrated with Ethno-SSI and the Ethno-VR museum as a local ethnosience learning resource. During the implementation phase, students carried out inquiry projects exploring the spices in Wedhang Uwuh through activities such as interviews to examine societal perspectives and socioscientific issues, field observations, and the design

and execution of Ethno-SSI inquiry projects in the laboratory. The outcomes were documented in student worksheets and the Ethno-VR museum learning media. A comparative analysis of the quality assessment scores for the Ethno-VR products and student worksheets developed during the inquiry projects is presented in Figure 4.

In this research, the Ethno-VR Wedhang Uwuh museum was compared with other products, as shown in Figure 4. Overall, the results indicate that students demonstrated excellent knowledge and skills in developing Ethno-VR spice museums. The Ethno-VR products for Nutmeg, Rendang, and Wedhang Uwuh received high scores (average > 3.75 out of 5) across visual, content, and adaptive components, including socioscientific issues on the pros and cons of herbal drinks, effectively supporting scientific and technological literacy. These findings suggest that students were generally capable of designing effective, user-friendly Ethno-VR museums that also enhance science and technology literacy [13], [14].



**Fig. 4.** Comparison of the average scores of the Ethno-VR quality assessment

Student feedback indicated that the narration at the Ethno-VR Wedhang Uwuh Museum was clear, though a slightly higher audio volume would improve audibility. The gallery content, including photos of various Wedhang Uwuh types, interview videos, historical background, and related information, was highly rated. Suggested improvements included adding decorative elements, such as vases, lighting, wall ornaments, and seating in front of the video areas, to create a more immersive experience. Overall, the gallery effectively conveyed knowledge of Wedhang Uwuh, covering both cultural and scientific aspects. Previous research supports that VR-based ethnosience learning media can enhance engagement, scientific literacy, and cultural appreciation, while integrating local wisdom through Ethno-VR strengthens contextual learning and promotes understanding of sustainability and SDG 4 [15].

## 4 Conclusion

The research resulted in the successful development of Ethno-VR Media for the Wedhang Uwuh Museum, providing a transdisciplinary platform that explores the chemical, cultural, and health dimensions of traditional spices. Through the integration of the Ethno-SSI and IPjLM models, the media provides a virtual space for exploring phytochemical profiles and organoleptic data in a way that is highly accessible to students. This study demonstrates the feasibility of using VR as a "cultural-technological bridge." Theoretically, it shows how indigenous knowledge can be digitized into a structured science curriculum. Practically, the high validation scores from experts and positive user perceptions suggest that Ethno-VR is a viable tool for supporting SDG 4 by making science education more inclusive and

contextually relevant. The primary limitation of this study is its focus on media development and user perception rather than longitudinal empirical testing. While students perceived the media as helpful for their literacy, this study did not employ formal pre- and post-tests to quantify actual knowledge gains. Future research should implement a controlled experimental design to measure the specific impact of Ethno-VR on student achievement scores and use advanced analytical chemistry tools (such as GC-MS) to further validate the scientific content within the virtual museum.

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