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Development of Ethnoscience-Based Digital Student Worksheets to Improve Scientific Literacy and Critical Thinking Skills of Elementary School Students

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ABSTRACT

Science and Social Studies (IPAS) learning in elementary schools still faces challenges in strengthening students' scientific literacy and critical thinking skills because the learning process tends to be textual, less contextual, and has not optimally integrated local culture and digital technology. This study aims to develop an ethnoscience-based digital student worksheet (LKPD) that is valid, practical, and effective in improving elementary school students' scientific literacy and critical thinking skills. The research employed a Research and Development (R&D) method using the ADDIE model, which consists of analysis, design, development, implementation, and evaluation stages. The research subjects involved 28 elementary school students. Data were collected through observation, interviews, questionnaires, tests, and documentation, and then analyzed using descriptive statistics and the N-gain test. The results showed that the ethnoscience-based digital LKPD obtained an average validation score of 91.1%, categorized as highly valid. The implementation of the product demonstrated an improvement in scientific literacy with an N-gain score of 0.71 and critical thinking skills with an N-gain score of 0.69. The integration of local culture, interactive multimedia, and project-based learning proved to enhance students' engagement, scientific reasoning, and problem-solving abilities. These findings confirm that the ethnoscience-based digital LKPD is effective in supporting contextual IPAS learning and 21st-century learning in elementary schools.

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1. INTRODUCTION

Ethnoscience in elementary school learning is regarded as an approach capable of connecting scientific concepts with students' local culture. This approach positions culture not only as a context but also as a source of knowledge that builds meaningful, reflective, and contextual learning experiences. In science and social studies learning (IPAS),

ethnoscience helps students understand natural phenomena through cultural practices closely related to their daily lives, thereby enhancing learning engagement, conceptual understanding, and students' scientific literacy [1], [2]. In addition, this approach strengthens students' character, cultural identity, and ecological awareness, making learning more humanistic and contextual [3], [4].

The urgency of ethnoscience-based learning has become increasingly important because elementary school students' scientific literacy still faces various challenges. Scientific literacy is not only related to mastering concepts but also to the ability to think critically, understand scientific phenomena, make rational decisions, and solve evidence-based problems [5]. However, science and social studies learning (IPAS) remains predominantly textual and memorization-oriented, thus providing limited support for higher-order thinking skills and students' scientific reasoning [6], [7]. This condition is exacerbated by the underutilization of local culture as a contextual learning resource, even though traditional community practices are closely related to scientific concepts. Research indicates that ethnoscience-based learning and instructional materials can improve scientific literacy, environmental awareness, and students' understanding of the nature of science through contextual activities [8], [9].

On the other hand, elementary school students' critical thinking skills also remain a challenge because science and social studies learning (IPAS) is often conducted in a one-way manner and provides limited opportunities for scientific exploration. As a result, students tend to receive information rather than construct knowledge through inquiry and problem-solving, causing scientific inquiry and reflective thinking to develop less optimally [10], [11]. Therefore, learning innovation is needed to integrate local culture, scientific activities, and digital technology in a comprehensive manner.

The development of educational technology provides opportunities through the use of digital student worksheets (LKPD) that are more interactive, flexible, visual, and collaborative. Digital LKPDs are capable of integrating multimedia, videos, simulations, augmented reality, and project-based activities, thereby strengthening students' learning experiences [12], [13]. The use of digital technology in science and social studies learning (IPAS) has also been proven to increase learning motivation, student engagement, and understanding of abstract concepts in a more concrete manner [14]. In the implementation of the Merdeka Curriculum, ethnoscience-based digital LKPDs become strategic media for supporting contextual learning, differentiation, deep learning, and 21st-century competencies. Research shows that e-modules based on computational thinking and differentiated learning are able to significantly improve students' scientific literacy, while the integration of augmented reality can strengthen students' ecoliteracy and conceptual understanding [15], [16].

Nevertheless, research on ethnoscience-based digital LKPDs to improve elementary school students' scientific literacy and critical thinking skills is still limited. Most previous studies have focused more on multimedia or general learning models without integrating local culture, scientific literacy, critical thinking, and digital technology comprehensively [17], [18]. Therefore, the development of ethnoscience-based digital LKPDs is important to create contextual, interactive, and meaningful learning experiences. This study is directed

toward the development of ethnoscience-based digital LKPDs that are valid, practical, and effective in improving elementary school students' scientific literacy and critical thinking skills in science and social studies learning (IPAS), while simultaneously strengthening the integration of culture, technology, and humanistic as well as sustainable science learning.

2. METHOD

This study employed the Research and Development (R&D) method using the ADDIE framework (Analysis, Design, Development, Implementation, Evaluation) to develop an ethnoscience-based digital student worksheet (LKPD) aimed at improving elementary school students' scientific literacy and critical thinking skills. The selection of the ADDIE model was based on its systematic, flexible, and adaptive characteristics in developing digital teaching materials that meet the needs of 21st-century learning and are relevant to the implementation of the Merdeka Curriculum.

The analysis stage was conducted through observations, interviews, questionnaires, and documentation studies to identify students' needs, the characteristics of IPAS learning, local cultural potential, and problems related to scientific literacy in elementary schools. The design stage included the development of the digital LKPD structure, storyboard creation, integration of ethnoscience, critical thinking activities, and interactive multimedia based on deep learning and TPACK approaches.

Furthermore, the development stage involved product preparation, validation by material, media, and language experts, as well as product revision based on validators' feedback. In the implementation stage, the digital LKPD was tested in IPAS learning at elementary schools through project-based learning and local cultural exploration to measure its practicality as well as students' and teachers' responses. The evaluation stage was conducted both formatively and summatively through the analysis of validity, practicality, effectiveness, improvements in scientific literacy, and students' critical thinking skills using descriptive analysis and N-gain analysis.

3. RESULTS AND DISCUSSION

The identification of problems in IPAS learning at elementary schools in Pontianak City was conducted through observations, teacher interviews, analysis of the Merdeka Curriculum documents, and questionnaires on the needs of students and teachers, focusing on scientific literacy, critical thinking, digital media, local culture integration, and contextual learning. The analysis results showed that learning activities were still dominated by textual and teacher-centered approaches, so student involvement in exploratory, investigative, and reflective activities had not been optimal in supporting scientific literacy and critical thinking skills. In addition, teachers still faced limitations in developing innovative technology-based teaching materials and ethnoscience approaches aligned with the characteristics of the Merdeka Curriculum. Therefore, the development of ethnoscience-based digital student worksheets (LKPD) integrating local culture, interactive multimedia, and project-based learning is needed to make IPAS learning more contextual and meaningful.

Table 1. Identification of Problems and Needs in IPAS Learning

Identification Focus	Main Findings	Indicators	Data Sources
IPAS Learning	Learning is still textual and teacher-centered	Low student exploration and investigation	Observation, interviews
Scientific Literacy	Scientific literacy has not been optimal	Difficulty connecting concepts with real-life situations	Pre-test, observation
Critical Thinking	Analytical and problem-solving skills are still low	Limited HOTS activities	Observation, student assignments
Learning Media	Interactive digital media are not yet optimal	Learning still relies on textbooks	Interviews, documentation
Ethnoscience Integration	Local culture has not been utilized in IPAS	Learning is less contextual	Observation, document study
Teacher Needs	Teachers require innovative digital LKPD	Interactive and contextual teaching materials are still limited	Questionnaires, interviews
Student Needs	Students prefer visual and interactive learning	High interest in digital media	Student questionnaires
IPAS Learning Outcomes	Learning outcomes emphasize scientific literacy and real-life contexts	Deep learning and project activities are not yet optimal	Document analysis
Merdeka Curriculum	Differentiated learning and project implementation still face obstacles	Adaptation of teaching materials is not yet optimal	Interviews, documentation

The identification results indicate that IPAS learning in elementary schools still faces challenges in developing students' scientific literacy and critical thinking skills. Learning activities still focus on content delivery and have not optimally provided exploratory experiences based on real-life contexts. The integration of local culture as a source of ethnoscience is also still limited, causing IPAS concepts to remain insufficiently connected to students' daily lives. Furthermore, teachers still experience limitations in developing digital teaching materials that align with the characteristics of the Merdeka Curriculum, particularly in integrating technology, differentiated learning, and critical thinking activities. These conditions indicate the need for developing ethnoscience-based digital LKPD that are interactive, contextual, and rooted in local culture to support students' scientific literacy and critical thinking skills.

The identification of scientific literacy and critical thinking skills through diagnostic tests, observations, assignment analysis, and interviews revealed that most students were still at the basic level, particularly in aspects of data interpretation, scientific reasoning, and contextual problem-solving. Learning activities that are still predominantly theoretical have caused students to be less accustomed to conducting independent scientific exploration, investigation, and reflection. Therefore, innovations in ethnoscience- and digital technology-based learning are needed to increase student engagement in IPAS learning in a more contextual, interactive, and meaningful manner.

Table 2. Identification of Scientific Literacy and Critical Thinking Levels in IPAS Learning

Identification Aspect	Main Findings	Indicators	Techniques
Understanding of Science Concepts	Understanding is still partial and memorization-based	Difficulty explaining scientific phenomena	Diagnostic tests, observation
Scientific Reasoning	Scientific reasoning is still low	Unable to draw conclusions based on evidence	Essay tests, interviews
Contextual Scientific Literacy	IPAS concepts are difficult to relate to real life	Low application of concepts	Learning observation
Information Analysis	Analysis of scientific information is still limited	Difficulty distinguishing facts from opinions	Critical thinking tests
Problem Solving	Problem-solving skills are not yet optimal	Difficulty solving contextual problems	Assignment analysis
Scientific Argumentation	Logical argumentation has not yet developed	Answers are still descriptive	Discussions, interviews
Exploratory Activities	Investigative involvement is still low	Passive and teacher-centered learning	Classroom observation
Local Culture Integration	Local culture has not been utilized	Learning is less contextual	Documentation study
Digital Media	Interactive media are not yet optimal	Students are more interested in visual learning	Student questionnaires
Learning Needs	Digital ethnoscience-based IPAS learning is needed	Need for exploratory and contextual activities	Questionnaires, interviews

The identification results indicate that elementary school students' scientific literacy and critical thinking skills still need to be strengthened, particularly in the aspects of scientific reasoning, information analysis, problem-solving, and scientific argumentation. Most students still understand IPAS concepts theoretically and are not yet able to relate them to real-life phenomena. Learning activities that are still dominated by teacher-centered approaches have caused exploration and scientific investigation activities to remain underdeveloped. In addition, the utilization of local culture as a source of ethnoscience and the use of interactive digital media in IPAS learning are still limited. These conditions demonstrate the need for the development of ethnoscience-based digital LKPD that are contextual, exploratory, and technology-based to improve students' scientific literacy and critical thinking skills.

The analysis of local cultural potential through observations, interviews, questionnaires, and documentation studies showed that local culture has great potential as a source of ethnoscience that can be integrated into contextual and real-life experience-based learning activities. Furthermore, students demonstrated a high interest in visual and interactive digital media, while teachers required digital LKPD that support differentiated learning, critical thinking, and scientific literacy in accordance with the characteristics of 21st-century learning.

Table 3. Analysis of the Potential of Ethnoscience Sources in IPAS Learning

Analysis Focus	Main Findings	Indicators	Data
Local culture	Potential as a source of ethnoscience	Environmental and conservation practices relevant to IPAS	Observation, interviews
Ethnoscience integration	Not yet optimally implemented	Learning materials are still less contextual	Documentation, observation
Student characteristics	Students prefer visual-interactive media	High interest in digital multimedia	Student questionnaires
Digital media	Teachers need interactive worksheets	The need for exploration-based multimedia	Interviews, questionnaires
21st-century learning	Strengthening 4C skills and scientific literacy is needed	Critical thinking and collaboration are not yet optimal	Observation
Merdeka Curriculum	Contextual teaching materials are still limited	Project-based learning has not been optimally implemented	Interviews, documentation
Learning technology	Digital media are still minimally used	Learning is predominantly book-based	Classroom observation
Scientific literacy	Scientific reasoning is still low	Problem-solving skills have not yet developed	Pre-test, observation
Product needs	Digital ethnoscience worksheets are needed	Must be interactive and contextual	Questionnaires, interviews
Development basis	Data support product development	In accordance with the actual needs of schools	Data triangulation

The analysis results indicate that local culture has great potential as a source of ethnoscience in IPAS learning because it is directly related to students' daily lives. However, this potential has not been optimally utilized, resulting in learning that still tends to be abstract and less contextual. Observations, interviews, and questionnaires revealed that students are more interested in interactive multimedia-based learning, while teachers require digital teaching materials that support 21st-century learning, scientific literacy, and critical thinking in line with the Merdeka Curriculum. In addition, the implementation of differentiated and project-based learning still requires innovative teaching materials. These findings form the basis for the development of digital ethnoscience-based worksheets to create IPAS learning that is contextual, interactive, and relevant to students' needs in the digital era.

The conceptual design of digital ethnoscience-based worksheets was developed based on an analysis of students' needs, teachers' needs, IPAS characteristics, the learning outcomes of the Merdeka Curriculum, and the potential of local culture. The worksheets were designed by integrating scientific literacy, critical thinking, local culture, and digital technology through culture-based phenomena, exploratory project activities, interactive multimedia, and assessments that support students' scientific reasoning and problem-solving skills. This design also refers to the principles of deep learning, differentiated learning, and the TPACK approach to create meaningful learning experiences in accordance with 21st-century characteristics. The integration of ethnoscience helps students understand IPAS

concepts through cultural and environmental contexts, making learning more authentic and reflective.

Table 4. Conceptual Design of IPAS Learning Worksheets

Component	Core Design	Purpose	Integration
Worksheet structure	Orientation, exploration, project, reflection, evaluation	Facilitate the learning process	Contextual deep learning
Ethnoscience	Local culture-based IPAS materials	Connect science with real-life situations	Local wisdom
Scientific literacy	Observation, investigation, scientific reasoning	Improve scientific literacy	Scientific literacy
Critical thinking	Analysis of contextual problems	Develop HOTS and problem-solving skills	Critical thinking
Multimedia	Videos, animations, images, QR codes	Increase student engagement	Digital learning
Project-based learning	Environment-based ethnoscience projects	Build authentic learning experiences	PjBL
Differentiation	Variation in activities and media	Adjust to students' needs	Differentiated learning
Digital technology	Flexible digital-based worksheets	Support 21st-century learning	TPACK & Society 5.0
Evaluation	Assessment of literacy and critical thinking	Measure learning effectiveness	Assessment for learning
Visual design	Simple and interactive appearance	Increase learning motivation	User-friendly

The results of the conceptual design indicate that the digital ethnoscience-based worksheets were developed as IPAS learning tools that integrate local culture, scientific literacy, critical thinking, and digital technology in a comprehensive manner. The worksheet structure includes observation, exploration, ethnoscience projects, reflection, and evaluation activities to support contextual and meaningful learning. Interactive multimedia such as videos, animations, images, and QR codes are utilized to enhance student engagement. In addition, the worksheets emphasize scientific reasoning, problem-solving, and project-based learning so that students can develop critical thinking skills through authentic learning experiences based on local culture. These findings demonstrate that digital ethnoscience-based worksheets have the potential to support the implementation of the Merdeka Curriculum and 21st-century learning in a more interactive and innovative way.

The identification of material structure, learning objectives, and indicators of scientific literacy and critical thinking was conducted through an analysis of the IPAS learning outcomes in the Merdeka Curriculum, elementary school students' characteristics, the needs of 21st-century learning, and the integration of ethnoscience based on local culture. The materials were designed contextually by linking local cultural phenomena with scientific concepts. The learning objectives focus on the development of scientific literacy, scientific reasoning, problem-solving, and critical thinking through observation, investigation, reflection, and ethnoscience project activities. Furthermore, the learning indicators were systematically integrated into the aspects of knowledge, skills, and scientific attitudes in accordance with the principles of deep learning and the Merdeka Curriculum. This

development also considers interactive digital learning to enhance student engagement and higher-order thinking skills in IPAS learning.

Table 5. Structural Components of the Ethnoscience-Based LKPD for IPAS Learning

Component	Main Findings	Indicators	Integration
IPAS material structure	Materials are based on local culture and environment	Contextual and applicable	Ethnoscience & contextual learning
Learning materials	Include observation and cultural exploration	Real learning experiences	Project-based learning
Learning objectives	Develop scientific literacy and critical thinking	Scientific reasoning & problem solving	Scientific literacy
IPAS objectives	Connect concepts with real-life situations	Contextual understanding	Contextual learning
Scientific literacy	Identify and explain scientific phenomena	Observation & data interpretation	Inquiry learning
Scientific literacy	Use scientific evidence	Scientific argumentation	Evidence-based learning
Critical thinking	Analyze problems and solutions	Critical reasoning	HOTS
Critical thinking	Evaluate information and arguments	Reflective thinking	Problem solving
Digital integration	Supported by multimedia and digital LKPD	Visual-interactive learning	TPACK & digital learning
Evaluation	Assessment of literacy and critical thinking	Tests, observation, projects	Authentic assessment

The identification results indicate that IPAS materials need to be arranged contextually by integrating local culture and ethnoscience activities so that students can more easily understand scientific concepts in everyday life. The learning objectives are focused on developing scientific literacy, scientific reasoning, problem solving, and critical thinking through observation, investigation, projects, and scientific reflection. The learning indicators are designed to measure students' abilities in analyzing scientific phenomena, using evidence, evaluating problems, and constructing logical arguments. These findings emphasize the importance of integrating ethnoscience and digital technology into IPAS learning in accordance with the characteristics of the Merdeka Curriculum.

The preparation of the flowchart and storyboard for the ethnoscience-based digital LKPD was conducted based on IPAS learning needs, elementary school students' characteristics, local culture, and 21st-century learning. The flowchart illustrates the learning process starting from orientation, exploration, ethnoscience projects, reflection, and evaluation, while the storyboard contains page designs, interactive multimedia, navigation, as well as scientific literacy and critical thinking activities. The LKPD display was designed to be simple and user-friendly with support from images, videos, animations, QR codes, and digital links to increase student engagement. The integration of local culture and ethnoscience projects helps connect IPAS concepts with students' real-life experiences.

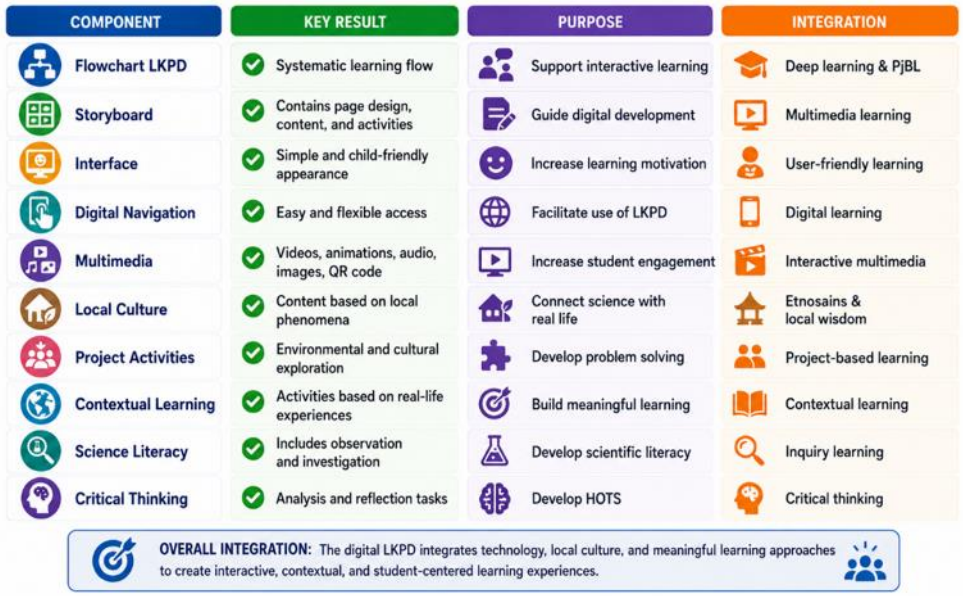

Figure 1. Structural Design Components of the Ethnoscience-Based LKPD for IPAS Learning

The results of the flowchart and storyboard development show that the ethnoscience-based digital LKPD was systematically, interactively, and contextually designed through stages of problem orientation, local culture exploration, ethnoscience projects, reflection, and evaluation of scientific literacy and critical thinking. Interactive multimedia design and the integration of local culture help create authentic, meaningful, and relevant learning experiences for students. These findings indicate that the ethnoscience-based digital LKPD has the potential to improve student engagement, scientific literacy, and critical thinking skills in accordance with the characteristics of the Merdeka Curriculum.

The preparation of the research instruments was conducted systematically to support the development and evaluation of the ethnoscience-based digital LKPD in IPAS learning. The instruments included needs and user response questionnaires, expert validation sheets, scientific literacy and critical thinking tests, observation sheets, and interview guidelines for teachers and students. The instrument development referred to indicators of scientific literacy, scientific reasoning, problem solving, and contextual learning in line with the characteristics of the Merdeka Curriculum and 21st-century learning. In addition, the instruments were designed to comprehensively measure the validity, practicality, and effectiveness of the LKPD through quantitative and qualitative approaches. The instrument development also considered the integration of local culture, ethnoscience projects, interactive multimedia, and exploratory activities in IPAS learning.

Table 6. Blueprint of the Assessment Instruments for the Ethnoscience-Based LKPD in IPAS Learning

Instrument	Focus	Indicators	Purpose
Student questionnaire	Digital media needs	Interest in LKPD and multimedia	Identify students' needs
Teacher questionnaire	Teaching material needs	LKPD based on the Merdeka Curriculum	Identify teachers' needs
Material validation	Feasibility of IPAS content	Scientific literacy and ethnoscience	Product content validation
Media validation	Multimedia quality	Display and navigation	Media validation
Language validation	Language readability	Clarity and age appropriateness	Language validation
Scientific literacy test	Scientific literacy	Observation and reasoning	Measure scientific literacy
Critical thinking test	Students' HOTS	Analysis and problem solving	Measure critical thinking
Observation	Learning activities	Participation and exploration	Observe implementation
Teacher interview	Teachers' perceptions	Ease of use and effectiveness of LKPD	Teacher qualitative data
Student interview	Learning experiences	Motivation and conceptual understanding	Students' responses

The results of the instrument development indicate that all instruments were designed in an integrated manner to measure the needs, validity, implementation, and effectiveness of the ethnoscience-based digital LKPD in IPAS learning. Questionnaires were used for analyzing students' and teachers' needs, validation sheets were used to assess content, media, and language, while scientific literacy and critical thinking tests were developed based on indicators of scientific literacy, scientific reasoning, and problem solving. In addition, observations and interviews were used to measure student engagement, learning effectiveness, and user responses. These findings indicate that the instruments support systematic product evaluation in accordance with the characteristics of 21st-century IPAS learning and the Merdeka Curriculum.

The development of the digital LKPD was carried out by integrating ethnoscience, interactive multimedia, and exploratory activities to improve elementary school students' scientific literacy and critical thinking skills. IPAS materials were presented contextually through images, videos, animations, QR codes, and local culture-based activities so that students could understand scientific concepts through real experiences. Learning activities were designed based on observation, investigation, problem solving, and project-based learning to encourage scientific reasoning and active student engagement. The integration of multimedia and digital technology also supports engaging and flexible learning that aligns with the characteristics of 21st-century education and the Merdeka Curriculum.

Table 7. Components of the Development Results of Ethnoscience-Based LKPD for IPAS Learning

Components	Development Results	Purpose	Integration
Digital LKPD	Interactive digital format	Supporting flexible learning	Digital learning
Contextual images	Cultural and local environmental visuals	Facilitating IPAS understanding	Visual learning
Learning videos	Local cultural exploration videos	Increasing learning motivation	Multimedia learning
Animation	Visualization of abstract concepts	Clarifying scientific concepts	Interactive multimedia
QR code	Access to videos and learning resources	Facilitating access to information	Technology integration
Ethnoscience activities	Exploration of culture and environment	Connecting science with real life	Ethnoscience & contextual learning
Exploration activities	Local observation and investigation	Developing scientific inquiry	Inquiry learning
Critical thinking	Analytical and problem-solving tasks	Developing HOTS	Critical thinking
Project-based learning	Local culture-based projects	Developing collaboration and creativity	PjBL
Scientific literacy	Scientific reasoning and data interpretation	Improving scientific literacy	Scientific literacy

The development results indicate that the ethnoscience-based digital LKPD was successfully designed by integrating interactive multimedia such as images, videos, animations, and QR codes to support engaging and contextual IPAS learning. The materials were developed based on local culture and the surrounding environment through investigation activities, problem solving, reflection, and ethnoscience projects, enabling the enhancement of students' engagement, scientific reasoning, scientific literacy, and critical thinking skills. The integration of digital technology and project-based learning demonstrates that the LKPD has the potential to support innovative IPAS learning in accordance with 21st-century learning characteristics and the Merdeka Curriculum.

Product validation conducted by material, media, and language experts showed that the ethnoscience-based digital LKPD was categorized as highly valid, with minor revisions in aspects of language, multimedia, and the strengthening of critical thinking activities. The validation was carried out based on indicators of digital teaching materials, scientific literacy, and contextual learning. These findings confirm that the product has met the feasibility standards in terms of content, media, and language, making it suitable for use in ethnoscience- and digital technology-based IPAS learning.

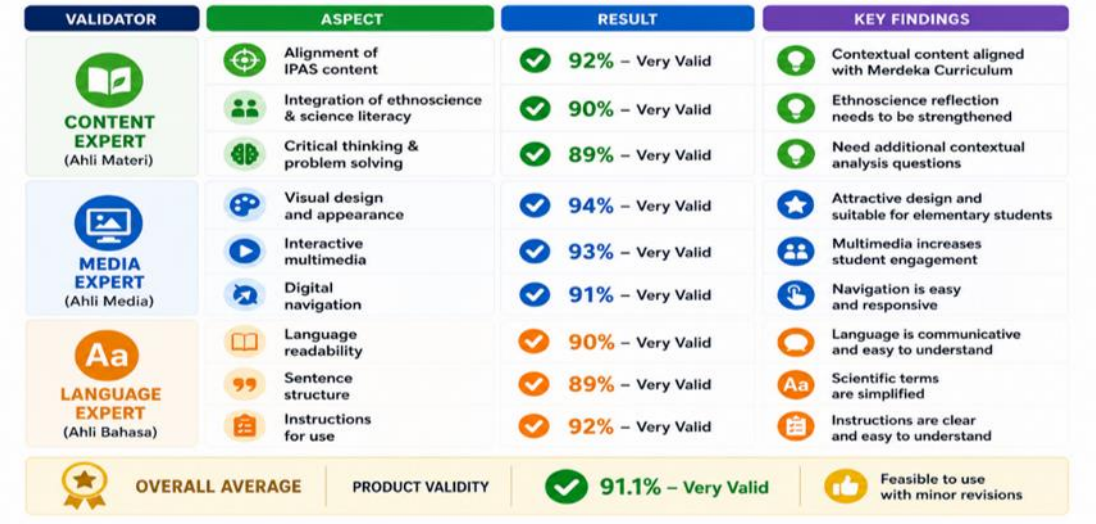

Figure 2. Expert Validation of the Development of Ethnoscience-Based LKPD for IPAS Learning

The validation results revealed that the ethnoscience-based digital LKPD obtained an average score of 91.1%, categorized as highly valid by material, media, and language experts. Material experts assessed that the LKPD was aligned with the IPAS learning outcomes of the Merdeka Curriculum and successfully integrated ethnoscience, scientific literacy, and critical thinking in a contextual manner. Media experts evaluated the appearance, interactive multimedia, and digital navigation as attractive, while language experts considered the language to be communicative and easy to understand. Minor revisions were made to the multimedia display, usage instructions, and contextual analysis activities. These findings indicate that the LKPD is appropriate for use as an IPAS learning medium to support scientific literacy and critical thinking among elementary school students.

Figure 3. Product Revision of the Development of Ethnoscience-Based LKPD for IPAS Learning

The LKPD revisions were conducted based on expert suggestions to improve the suitability of the material, the integration of ethnoscience and scientific literacy, the

simplification of language, the strengthening of critical thinking and problem-solving activities, as well as the optimization of interactive multimedia and digital navigation. The development of images, videos, animations, and QR codes was carried out to make the LKPD more attractive and easier for elementary school students to use. The gradual revisions resulted in a product categorized as highly valid and suitable for implementation in ethnoscience- and digital technology-based IPAS learning.

The revision results showed that the ethnoscience-based digital LKPD was improved in aspects of material content, ethnoscience integration, interactive multimedia, digital navigation, and language readability based on validator feedback. Revisions included the addition of local cultural content, exploratory activities, observation tasks, problem-solving exercises, and scientific reflection activities to strengthen students' scientific literacy and critical thinking skills. Visual displays, videos, animations, and QR codes were also enhanced to become more interactive and aligned with the characteristics of elementary school students. After revision, the LKPD achieved a highly valid category and was considered suitable for use in IPAS learning based on the Merdeka Curriculum.

A limited trial was conducted to determine the implementation, practicality, and students' responses toward the ethnoscience-based digital LKPD through project-based learning and local cultural exploration. The LKPD utilized interactive multimedia such as images, videos, animations, and QR codes to assist students in understanding IPAS concepts concretely. The implementation results showed that the LKPD was able to increase active participation, learning motivation, scientific exploration, and student engagement in project-based learning activities. In addition, students demonstrated high enthusiasm toward digital learning that connected IPAS concepts with local culture and the surrounding environment.

Table 8. Limited Trial Implementation of the Ethnoscience LKPD in IPAS Learning

Implementation Aspect	Observation Indicators	Main Findings
Limited trial	Learning implementation	The LKPD was implemented effectively, systematically, and in accordance with the learning sequence.
Digital LKPD implementation	Utilization of digital media	Students actively used the digital LKPD during IPAS learning activities.
Ethnoscience integration	Exploration of local culture and environment	Learning became more contextual and closely related to students' experiences.
Exploration activities	Scientific inquiry and simple observation	Students became more active in observing, questioning, and conducting investigations.
Student engagement	Discussion, collaboration, and interaction	Student participation and communication improved during the learning process.
Critical thinking	Problem solving and reflection	Students' analytical and reflective abilities began to develop.
Interactive multimedia	Use of videos, animations, images, and QR codes	Digital media increased the attractiveness and interactivity of learning.
Student responses	Learning motivation and comfort	Students showed positive responses and found learning more enjoyable.
Teacher responses	Practicality of LKPD usage	Teachers considered the LKPD easy to use and supportive of contextual learning.
Scientific literacy	Scientific literacy and reasoning	Students began to relate IPAS concepts to real-life phenomena.

The results of the limited trial indicated that the ethnoscience-based digital LKPD functioned well and received positive responses from both students and teachers. Project-based learning and local cultural exploration increased student engagement in observation, discussion, investigation, and contextual problem solving. Interactive multimedia such as videos, animations, images, and QR codes made learning more interesting and easier to understand. In addition, students demonstrated improved learning motivation, scientific inquiry skills, and confidence in presenting their observations. Teachers assessed that the LKPD was able to create a more contextual, interactive, and Kurikulum Merdeka-oriented IPAS learning environment. These findings indicate that the LKPD has a high level of practicality and implementation feasibility in improving elementary students' scientific literacy and critical thinking skills.

A large-scale trial was conducted to determine the practicality and effectiveness of the ethnoscience-based digital LKPD through project-based learning, local cultural exploration, and scientific inquiry. The data were analyzed using descriptive analysis and N-gain. The results showed that the LKPD had a high level of practicality and significantly improved student learning engagement. Furthermore, the LKPD was proven effective in improving learning outcomes, scientific literacy, scientific reasoning, and students' critical thinking skills through contextual learning based on local culture and interactive multimedia.

Table 9. Large-Scale Trial of the Ethnoscience LKPD in IPAS Learning

Large-Scale Trial Aspect	Implementation Results	Measurement Indicators	Findings
Product practicality	The LKPD was easy for students and teachers to use	Ease of use and digital accessibility	The product was practical and flexible
Learning implementation	Learning was interactive and contextual	Project activities and local cultural exploration	Students were active during learning
Student learning outcomes	Learning achievement scores increased	Comparison of pretest and posttest results	Learning outcomes improved significantly
Scientific literacy	Scientific literacy skills improved	Scientific reasoning and data interpretation	Students better understood IPAS concepts
Critical thinking	Analytical and problem-solving skills improved	HOTS and scientific reflection	Students became more critical in solving problems
Student engagement	Participation and learning motivation increased	Discussion, collaboration, and exploration	Students became more enthusiastic and communicative
Interactive multimedia	Videos, animations, and QR codes supported concept understanding	Student interaction with digital media	Learning became more engaging
Ethnoscience integration	Local culture made learning more contextual	Connection of concepts with the surrounding environment	Concept understanding became more meaningful
Teacher responses	Teachers gave very positive responses	Practicality and effectiveness of the LKPD	Supported the implementation of Kurikulum Merdeka
Product effectiveness	The digital LKPD effectively improved student abilities	N-gain analysis and learning observation	The product was effectively used in elementary IPAS learning

The results of the large-scale trial showed that the ethnoscience-based digital LKPD had an excellent level of practicality and effectiveness in elementary school IPAS learning. The product was easy to use through simple navigation, interactive multimedia, and activities based on local culture. Project-based learning and cultural exploration increased student engagement in observation, scientific inquiry, and problem solving, while also improving learning outcomes, scientific literacy, scientific reasoning, and critical thinking. The use of images, videos, animations, and QR codes helped students understand IPAS concepts more concretely and attractively. Teachers also gave positive responses because the LKPD supported the implementation of Kurikulum Merdeka and 21st-century interactive and contextual learning.

Formative evaluation was conducted through expert validation, product revision, limited trials, observation, and user responses, while summative evaluation was conducted through pretest-posttest analysis involving 28 students using descriptive statistics, mastery percentage, and N-gain analysis. The evaluation results showed that the ethnoscience-based digital LKPD was able to improve student learning engagement, scientific reasoning, and problem-solving skills through contextual learning based on local culture and interactive multimedia. In addition, teachers and students gave highly positive responses regarding the practicality and effectiveness of the LKPD in supporting the implementation of Kurikulum Merdeka.

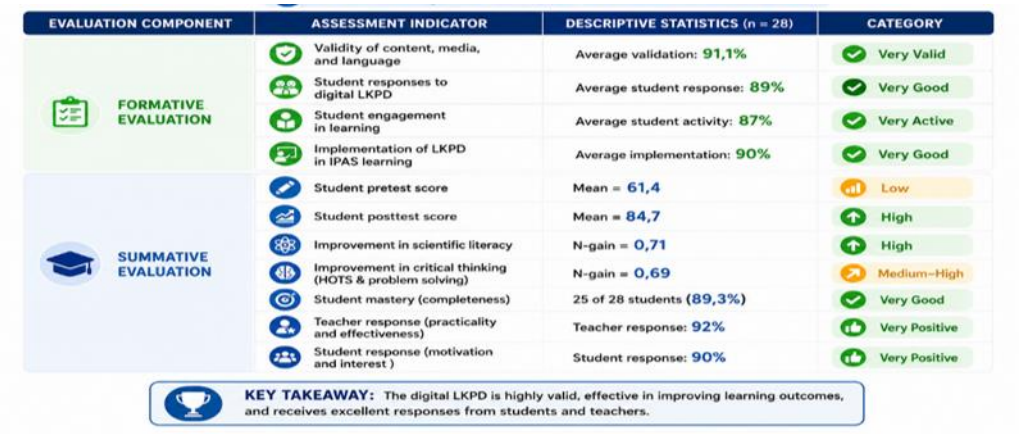

Figure 4. Evaluation of the Development of the Ethnoscience LKPD in IPAS Learning

The formative evaluation results showed that the ethnoscience-based digital LKPD obtained a “very valid” and “very good” category during the validation stage, limited trial, and learning implementation. Students demonstrated high engagement in project-based learning and local cultural exploration. The summative evaluation involving 28 students showed significant improvements in learning outcomes, scientific literacy, and critical thinking, with the average score increasing from 61.4 to 84.7. The N-gain for scientific literacy was 0.71, categorized as high, while critical thinking achieved 0.69, categorized as moderate to high, with learning mastery reaching 89.3%. Teachers and students also provided highly positive responses regarding the practicality and effectiveness of the product. These findings indicate that the ethnoscience-based digital LKPD effectively supports interactive and contextual IPAS learning in elementary schools.

The analysis of improvements in scientific literacy and critical thinking using descriptive statistics and N-gain based on pretest and posttest results showed that the ethnoscience-based digital LKPD was able to improve students' scientific literacy, scientific reasoning, data interpretation, problem solving, and critical thinking through contextual learning, interactive multimedia, and local cultural exploration. These findings confirm that the integration of ethnoscience and digital technology has a positive impact on the development of higher-order thinking skills among elementary school students.

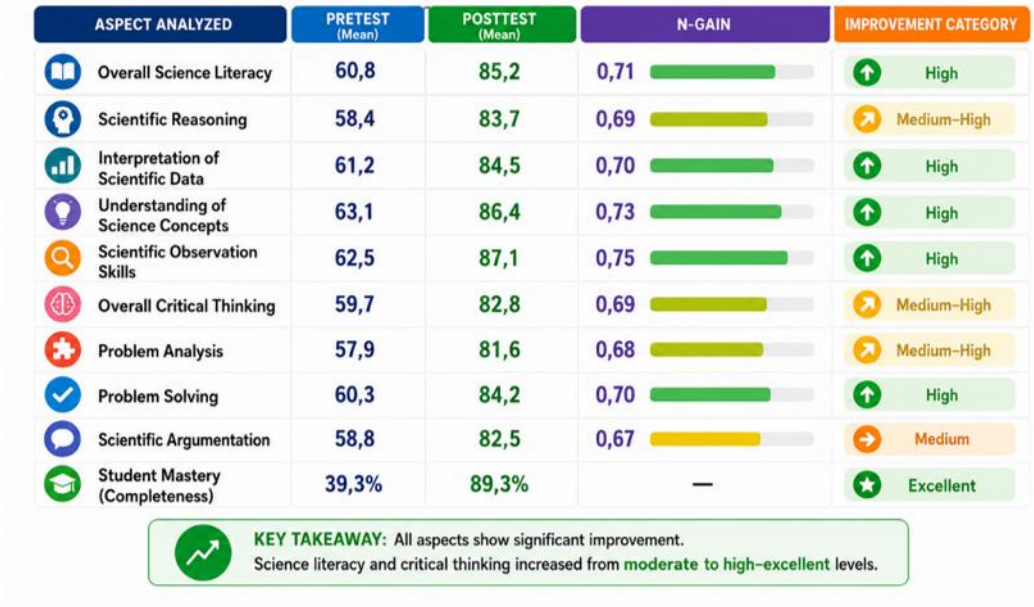

Figure 5. Analysis of the Improvement of Scientific Literacy and Critical Thinking in IPAS Learning Using the Ethnoscience LKPD

The results of the descriptive and N-gain analyses showed that the ethnoscience-based digital LKPD effectively improved elementary school students' scientific literacy and critical thinking skills. The average scientific literacy score increased from 60.8 to 85.2, with an N-gain value of 0.71 categorized as high. The improvement was especially visible in students' scientific reasoning, data interpretation, and understanding of IPAS concepts through contextual and exploratory learning activities. Students became more active in connecting scientific concepts with local culture and their surrounding environment, while the use of interactive multimedia such as videos, animations, images, and QR codes increased learning motivation and engagement during the learning process.

In addition, students' critical thinking skills also improved significantly, with the average score increasing from 59.7 to 82.8 and an N-gain value of 0.69 categorized as moderate to high. The improvement was mainly observed in students' abilities to analyze problems, solve problems systematically, and communicate logical arguments during scientific inquiry and project-based learning activities. Furthermore, the percentage of learning mastery increased from 39.3% to 89.3% after the implementation of the ethnoscience-based digital LKPD. These findings indicate that the integration of local culture, interactive multimedia, and project-based exploratory learning effectively supports

the development of students' scientific literacy and higher-order thinking skills in accordance with the objectives of the Merdeka Curriculum and 21st-century learning.

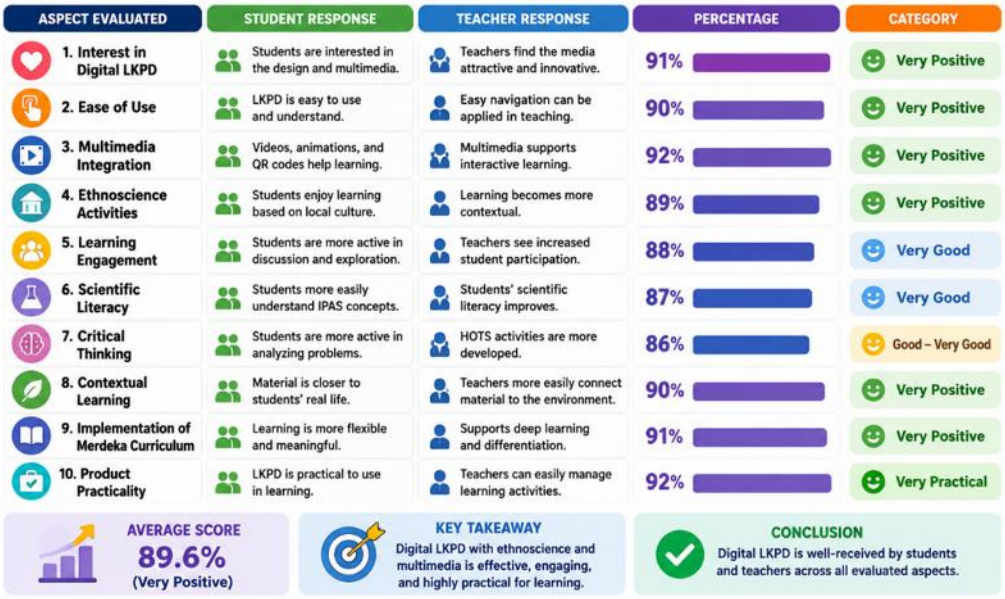

Figure 6. Student and Teacher Responses toward the Ethnoscience LKPD in IPAS Learning

The evaluation through questionnaires, interviews, observations, and reflections indicated that students responded very positively because the learning process became more engaging, interactive, and contextual through the use of videos, animations, QR codes, and ethnoscience-based activities related to the surrounding environment. Teachers also assessed that the digital student worksheets supported a more active, exploratory, and relevant science and social studies learning process in accordance with the needs of 21st-century education.

The evaluation results showed that both students and teachers gave highly positive responses to the use of ethnoscience-based digital worksheets in science and social studies learning. Students found the learning activities more interesting and easier to understand through videos, animations, images, and QR codes integrated with local cultural exploration. Student participation in discussions, observations, problem-solving, and scientific inquiry also increased. Teachers considered the worksheets practical to use and supportive of differentiated learning, project-based learning, and deep learning in line with the Merdeka Curriculum. The integration of ethnoscience helped connect science and social studies concepts with the surrounding environment, making learning more contextual and meaningful. These findings indicate that ethnoscience-based digital worksheets have a very high level of practicality and acceptance in improving elementary school students' scientific literacy and critical thinking skills.

The refinement of the final product was carried out based on the results of implementation, formative and summative evaluations, as well as feedback from teachers and students. Revisions focused on optimizing the materials, integrating ethnoscience, strengthening scientific literacy and critical thinking, improving interactive multimedia, and enhancing the digital interface and navigation to make them more effective and user-friendly. The improvement results demonstrated that the ethnoscience-based digital

worksheets became more interactive, contextual, and effective in enhancing students' scientific literacy and critical thinking through project-based learning and local cultural exploration.

Figure 7. Improvement of Ethnoscience-Based Worksheets for Science and Social Studies Learning

The refinement results indicated that the ethnoscience-based digital worksheets improved in terms of materials, learning activities, interactive multimedia, digital navigation, and visual design to align with the characteristics of elementary school students and the Merdeka Curriculum. Scientific literacy and critical thinking activities were strengthened through observation, scientific reasoning, problem-solving, and reflection based on local culture. Multimedia components such as videos, animations, and QR codes were also enhanced to increase student engagement and learning motivation. Teachers and students provided positive responses regarding the ease of use and the meaningfulness of contextual ethnoscience-based learning. Overall, the worksheets were considered highly feasible, practical, and effective in improving elementary school students' scientific literacy and critical thinking skills.

The establishment of ethnoscience-based digital worksheets as the final product was based on expert validation results, limited and large-scale trials, as well as formative and summative evaluations showing that the product fulfilled the aspects of validity, practicality, and effectiveness. The worksheets were designed by integrating ethnoscience, scientific literacy, critical thinking, interactive multimedia, and project-based learning according to the characteristics of the Merdeka Curriculum and 21st-century learning. The evaluation results demonstrated that the product was able to improve scientific literacy, scientific reasoning, problem-solving, and student engagement through the integration of local culture and digital technology. Teachers and students also provided highly positive responses regarding the interactivity and meaningfulness of the learning process.

Figure 8. Final Product of Ethnoscience-Based Worksheets for Science and Social Studies Learning

The final product evaluation results showed that the ethnoscience-based digital worksheets fulfilled all feasibility indicators as a valid, practical, and effective learning medium for elementary school science and social studies education. Product validity was demonstrated through expert assessment results with an average percentage of 91.1%, categorized as highly valid, while product practicality was reflected in the highly positive responses from teachers and students regarding ease of use, interactive multimedia display, and contextual learning based on local culture. In addition, the product effectiveness was evident from the improvement in students' learning outcomes, scientific literacy, and critical thinking skills after using the digital worksheets, with an N-gain score of 0.71 for scientific literacy and 0.69 for critical thinking skills. The integration of ethnoscience, project activities, scientific inquiry, and interactive multimedia successfully increased student engagement and learning motivation during science and social studies learning. These findings confirm that ethnoscience-based digital worksheets are appropriate to be used as a final product to support the implementation of the Merdeka Curriculum and 21st-century learning in elementary schools in a more interactive, contextual, and meaningful manner.

Discussion

The research findings showed that ethnoscience-based digital worksheets contributed significantly to improving the quality of elementary school science and social studies learning, particularly in students' scientific literacy and critical thinking skills. The product achieved very high validity with an average score of 91.1% from material, media, and language experts, indicating the suitability of the content, readability, media interactivity, and relevance to the Merdeka Curriculum. The integration of local culture made learning more contextual and meaningful because students learned scientific concepts through real-life experiences and their surrounding environment [19], [20].

The implementation of ethnoscience-based digital worksheets increased student involvement in project-based learning, scientific inquiry, observation, discussion, and

problem-solving activities. The use of interactive multimedia such as videos, animations, images, and QR codes enhanced learning motivation and helped students understand science and social studies concepts more concretely [21], [22]. Learning also became more flexible, collaborative, and student-centered in accordance with the characteristics of 21st-century learning and the deep learning approach promoted in the Merdeka Curriculum [23], [24].

Empirically, the N-gain results indicated significant improvement in scientific literacy with a score of 0.71 and critical thinking skills with a score of 0.69, particularly in scientific reasoning, data interpretation, problem-solving, and scientific argumentation. These findings demonstrate that the integration of ethnoscience, project-based learning, and digital multimedia effectively develops students' higher-order thinking skills [25], [26]. Theoretically and practically, this study confirms that ethnoscience-based digital worksheets can become an innovative approach to science and social studies learning that supports scientific literacy, critical thinking, creativity, collaboration, and students' ecological awareness in the Society 5.0 era [27], [28].

4. CONCLUSION

This study shows that the development of ethnoscience-based digital student worksheets through the ADDIE model successfully produced an elementary school science and social learning product that is valid, practical, and effective in improving students' scientific literacy and critical thinking skills. The integration of local culture, interactive multimedia, and project-based learning activities was able to create learning that is more contextual, exploratory, and meaningful in accordance with the characteristics of the Merdeka Curriculum and 21st-century learning. The results of expert validation indicated a very valid category, while the product implementation demonstrated highly positive responses from teachers and students regarding the practicality and interactivity of the digital worksheets. In addition, the results of descriptive analysis and N-gain showed significant improvements in students' scientific literacy, scientific reasoning, problem-solving abilities, and critical thinking skills after using the product. These findings confirm that ethnoscience-based digital worksheets are not only effective as a learning medium for science and social studies, but also make a strategic contribution to integrating scientific literacy, digital technology, and local wisdom in supporting more humanistic, innovative, and sustainable elementary school learning in the Society 5.0 era.

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