THE EFFECT OF TUMPEK WARIGA-BASED PROJECT-BASED LEARNING ON ELEMENTARY SCHOOL STUDENTS' CRITICAL THINKING AND COLLABORATION SKILLS IN INTEGRATED SCIENCE AND SOCIAL STUDIES LEARNING

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ABSTRACT

This study aimed to examine the effect of the Tumpek Wariga-based Project-Based Learning (PjBL) model on students' critical thinking and collaboration skills in science and social studies (IPAS) learning at SD Negeri Sumbersari. The study employed a quasi-experimental method using two research designs: a Pretest–Posttest Control Group Design for the critical thinking skills variable and a Static Group Comparison Design for the collaboration skills variable. The participants consisted of 17 students in the experimental group and 16 students in the control group. Critical thinking data were collected through a six-item essay test, while collaboration skills data were obtained through structured observations consisting of 12 indicators across five aspects. Data were analyzed using normality and homogeneity tests, paired samples t-test, Mann–Whitney U test, independent samples t-test, N-Gain analysis, and Cohen's d effect size. The results revealed that the Tumpek Wariga-based PjBL model had a positive effect on students' critical thinking skills, as indicated by an N-Gain score of 0.35 (moderate category) and an effect size of 0.38 (small category). The model also demonstrated a highly significant effect on collaboration skills, with the experimental group achieving an average score of 83.58% (very high category), significantly higher than that of the control group (51.56%), and an effect size of 5.402 (very large category). These findings suggest that the integration of local wisdom through the Tumpek Wariga-based PjBL model is effective in fostering elementary school students' critical thinking and collaboration skills.

Keywords: *Project-Based Learning, Tumpek Wariga, Ethnoscience, Critical Thinking Skills, Collaboration Skills, Elementary School*

A. Introduction

The transformation of education in the 21st century cannot be separated from the rapid development of digital technology, globalization, and the demands of the Industrial Revolution 4.0, which have shifted the focus of learning from merely acquiring knowledge to developing higher-order thinking skills and social competencies (Mulyani et al., 2021). Various international studies emphasize that modern education systems must prepare students to

possess critical thinking, creativity, communication, and collaboration skills as essential competencies for addressing increasingly complex global challenges (Shenkoya & Kim, 2023; Tikhonova & Raitskaya, 2023). However, the reality in schools indicates that learning practices are still largely dominated by conventional teacher-centered approaches that emphasize memorization of concepts, thereby limiting the development of these 21st-century skills (González-Pérez & Ramírez-Montoya, 2022). This condition reflects a gap between global competency demands and the actual instructional practices implemented in elementary schools.In this context, Project-Based Learning (PjBL) is considered one of the most relevant innovative approaches to address the needs of 21st-century education. PjBL positions students as active participants who are directly involved in inquiry processes, problem-solving, decision-making, and project completion related to real-life situations (Mirwanda et al., 2024; Setiawan et al., 2021). Through project activities, students not only acquire conceptual knowledge but also simultaneously develop critical thinking, communication, creativity, and collaboration skills. Previous studies have demonstrated that the implementation of PjBL enhances students' collaboration skills through structured group work, active discussions, and shared responsibilities in project completion (Sagala et al., 2019). Furthermore, the application of PjBL in science education has been shown to strengthen problem-solving abilities and increase student engagement in the learning process (Marzuki & Natsir, 2021).

Despite its potential benefits, the implementation of PjBL in elementary schools still faces several challenges, particularly regarding the limited integration of learning materials with students' cultural contexts and everyday experiences. Most learning projects remain general in nature and adopt global contexts that are distant from students' daily lives (Sholahuddin et al., 2021). Consequently, students often encounter difficulties in connecting scientific concepts with the socio-cultural environment in which they live. Learning becomes less meaningful because students focus primarily on completing tasks without understanding the relevance of the knowledge being learned to their real-

life experiences (Shofyana et al., 2022). This situation suggests that project-based learning that is not integrated with local contexts may reduce students' depth of understanding of scientific concepts.

Moreover, the implementation of PjBL, which often prioritizes academic achievement, tends to overlook social and cultural dimensions that are essential for developing contextual scientific understanding. Learning processes that do not incorporate local culture deprive students of opportunities to understand the relationship between scientific knowledge and the practices of the communities around them (Arfida et al., 2024). Therefore, an instructional approach is needed that can integrate scientific concepts with local wisdom, making learning more authentic, meaningful, and relevant to students' lived experiences.

One approach that can bridge this need is ethnoscience-based learning. Ethnoscience refers to an educational approach that integrates local knowledge and cultural practices into formal science education, enabling students to understand scientific concepts through familiar cultural contexts (Ardianti & Raida, 2022). The integration of ethnoscience into learning has been proven to enhance students' learning motivation, engagement, and conceptual understanding of science because students learn scientific concepts through phenomena closely related to their everyday lives (Hikmawati et al., 2020; Sari et al., 2023). Ethnoscience-based learning also provides opportunities for students to develop social skills such as collaboration, communication, and problem-solving through the collective exploration of local cultural practices (Fairus et al., 2024; Rahim et al., 2022).

Integrating ethnoscience into the PjBL model is believed to create more contextualized and meaningful learning experiences. In ethnoscience-integrated project-based learning, students not only study scientific concepts theoretically but also examine local cultural practices that embody scientific and ecological values (Gde et al., 2023). Through investigation, field observation, and the completion of projects based on local culture, students are encouraged to think critically about the relationship between traditional knowledge and

modern scientific concepts (Nurcahyani et al., 2021). Previous studies indicate that integrating ethnoscience into project-based learning significantly improves students' critical thinking skills because students are trained to evaluate, interpret, and connect various sources of knowledge within authentic contexts (Daulay & Asrizal, 2024).

In addition to enhancing critical thinking skills, ethnoscience integration positively influences students' collaboration skills. Learning activities based on local culture enable students to work together in exploring social and environmental phenomena familiar to them, fostering more active and meaningful interactions within learning groups (Fitri et al., 2024). Project activities involving environmental observations, group discussions, and presentations of investigation findings encourage students to share ideas, respect diverse opinions, and develop collective responsibility in completing tasks (Lumbu et al., 2024). Therefore, ethnoscience-based learning not only strengthens students' academic competencies but also develops social skills that are highly essential for life in the 21st century.

Preliminary observations conducted in Grade V science and social studies (IPAS) classes at SD Negeri Sumbersari revealed that project-based learning practices remain generic and make limited use of the students' surrounding environment. In one ecosystem learning project, students were instructed to create a diorama depicting the African savanna using images of animals such as zebras, lions, and giraffes obtained from the internet and textbooks. Although the project successfully produced visual products, it provided limited meaningful learning experiences because students had no direct connection with the context being studied. Most students were able to recognize foreign animals but lacked understanding of local plant species and ecosystems found in their own environment. This condition indicates that learning has not yet become fully contextualized and has not optimally integrated local wisdom as a learning resource for IPAS.

In fact, the community of Sumbersari in Central Sulawesi possesses rich local cultural

resources that can be integrated into IPAS learning, particularly the Bali-Hindu cultural traditions that continue to be strongly practiced by the local community. One of the traditions that remains preserved is the Tumpek Wariga ceremony, a cultural practice dedicated to honoring plants and based on the philosophy of Tri Hita Karana. This philosophy emphasizes harmony among humans, nature, and God as the foundation of a balanced life (Supriani et al., 2025; Swariga et al., 2024). In practice, Tumpek Wariga embodies not only spiritual values but also ecological knowledge related to plant conservation, environmental balance, and traditional agricultural practices that are highly relevant to ecosystem topics in IPAS learning (Wahyuni et al., 2023).

The ecological values embedded in the Tumpek Wariga tradition have significant potential to serve as contextual and authentic learning resources for elementary school students. Through the integration of this local cultural practice, students can understand ecosystem concepts, interactions among living organisms, and environmental conservation in a more concrete manner because these concepts are directly linked to cultural practices encountered in their daily lives. Furthermore, integrating Tumpek Wariga into the PjBL model enables students to engage in field observations, scientific investigations, group discussions, and collaborative project development based on local culture. These activities are expected to foster the development of students' critical thinking and collaboration skills more effectively.

Although numerous studies have examined the implementation of ethnoscience in science education, research specifically integrating the values of Tumpek Wariga into the PjBL model in elementary school IPAS learning remains very limited. Furthermore, studies investigating the simultaneous effects of ethnoscience integration on students' critical thinking and collaboration skills are still scarce (Septina, 2024; Lumbu et al., 2024). This research gap highlights the need for developing an instructional model that systematically combines project-based learning with local wisdom to support the enhancement of 21st-century competencies among elementary school students.

Based on the foregoing discussion, the implementation of a

Tumpek Wariga-based Project-Based Learning model is considered to have great potential for creating contextual, meaningful, and culturally relevant IPAS learning experiences. The integration of Tumpek Wariga values into learning is expected not only to help students achieve a deeper understanding of scientific concepts but also to foster critical thinking and collaboration skills through authentic project activities rooted in local culture. Therefore, this study is important to investigate the effect of a Tumpek Wariga-based Project-Based Learning model on students' critical thinking and collaboration skills in IPAS learning at SD Negeri Sumbersari.

B. Method

This study employed a quantitative approach using a quasi-experimental design, which allows researchers to investigate causal relationships in naturally formed groups without random assignment (Creswell & Creswell, 2018; Sugiyono, 2019). Two research designs were implemented: the Pretest-Posttest Control Group Design to assess students' critical thinking skills and the Static Group Comparison Design to evaluate students' collaboration skills. The participants consisted of 33 fifth-grade students from SD Negeri Sumbersari, comprising 17 students in the experimental group who received Tumpek Wariga-based Project-Based Learning (PjBL) instruction and 16 students in the control group who received conventional PjBL instruction.

Critical thinking skills (CTS) data were collected using a six-item essay test covering the indicators of interpretation, analysis, inference, evaluation, explanation, and self-regulation, adapted from the critical thinking framework proposed by Facione (2015). Meanwhile, collaboration skills data were obtained through structured observations using an observation sheet containing 12 indicators across five dimensions of collaboration. Data were analyzed using the Shapiro-Wilk normality test, Levene's homogeneity test, Mann-Whitney U test, Paired Samples t-test, Wilcoxon Signed-Rank test, Independent Samples t-test, Normalized Gain (N-Gain), and Cohen's d effect size to determine the magnitude of the treatment effect (Field, 2018; Cohen, 1988).

C. Result and Discussion

Table 1. Recapitulation of Validation Results of the Tumpek Wariga Learning Module

Assessment Aspects	Percentage (%)	Category
Content/Material Suitability	85.00	Very Valid
Linguistic Eligibility	87.50	Very Valid
Presentation and Graphic Suitability	83.33	Very Valid
Compatibility with the Tumpek Wariga Based PjBL Model	87.50	Very Valid
Amount	**85.63**	**Very Valid**

Based on the results of expert validation, the Tumpek Wariga learning module obtained an overall validity percentage of 85.63% with a very valid category. The highest percentage was obtained in the aspects of linguistic feasibility and suitability with the Tumpek Wariga - based PjBL model, each reaching 87.50%. These results indicate that the language used in the module is appropriate to the characteristics of elementary school students, communicative, easy to understand, and has represented Project Based syntax. Learning systematically.

Meanwhile, the content/material feasibility aspect obtained a score of 85.00% , which indicates that the material is in accordance with the learning outcomes of science and is able to support the development of students' critical thinking skills. The presentation and graphics aspect obtained the lowest score of 83.33%, although it is still in the very valid category. Overall, the validation results indicate that the module is suitable for use as a learning tool in research.

Table 2. Descriptive Statistics of Pretest and Posttest Critical Thinking Skills

Descriptive Statistics	Experimental Class	Control Class
Pretest	66.76	68.00
Posttest	77.82	73.06
Improvement	11.06	5.06

Based on the analysis, the average pretest score for the experimental class was 66.76 and the control class was 68.00. These scores indicate that students' initial critical thinking skills in both classes were relatively equal before the treatment was administered. After the learning process, the average posttest score for the experimental class increased to 77.82, while the average posttest score for the control class increased to 73.06. The increase in the experimental class reached 11.06 points, higher than the increase in the control class, which only increased by 5.06 points.

These results show that the application of the Project Based model Tumpek Wariga-based Project-Based Learning (PjBL) demonstrated greater improvement in critical thinking skills compared to control classes. This improvement occurred because students were actively involved in problem identification, information gathering, field investigations, and developing solutions to problems encountered during the project. These activities encouraged students to engage in more in-depth interpretation, analysis, evaluation, and conclusion-drawing.

This finding aligns with Yani's (2021) research, which states that the PjBL model can shape active, scientific, and reflective learners through systematic learning stages. Furthermore, research by Munira et al. (2024), Elfrida et al. (2023), Fitri et al. (2024), and Hikmawati et al. (2020) shows that ethnoscience- based learning can improve critical thinking skills because students not only receive concepts theoretically but also connect them to real-world phenomena relevant to their lives.

Table 3. Average Percentage of CTS Achievement per Pretest and Posttest Indicator

Indicator	Experiment Pre (%)	Experiment Post (%)	Δ Eks.	Control. Pre (%)	Post Control (%)	Δ Control
Interpretation	78.75	91.25	+12.50	73.75	82.50	+8.75
Analysis	82.50	87.50	+5.00	73.75	77.50	+3.75
Inference	76.25	86.25	+10.00	76.25	77.50	+1.25
Evaluation	71.25	85.00	+13.75	70.00	72.50	+2.50
Explanation	71.25	78.75	+7.50	70.00	72.50	+2.50
Self-Regulation	43.75	65.00	+21.25	38.75	50.00	+11.25

The results of the analysis per indicator showed that all critical thinking skills indicators in the experimental class increased after the implementation of the Tumpek Wariga -based PjBL model. The highest increase occurred in the self-regulation indicator at 21.25 points, followed by the evaluation indicator at 13.75 points and the interpretation indicator at 12.50 points. Meanwhile, the lowest increase occurred in the analysis indicator at 5.00 points, as this indicator had been in the high category since the pretest.

Improved self-regulation and evaluation demonstrate that students not only acquire new knowledge but

also learn to control their own thinking processes, evaluate their work results, and refine strategies used during project completion. These characteristics are among the key advantages of the PjBL model, which places students at the center of learning.

The results of this study align with the opinion of Syaban et al. (2024), who stated that an ethnoscience approach encourages students to integrate cultural and scientific knowledge through an in-depth analysis process. When students observe the Tumpek Wariga practice and relate it to the concept of ecosystems, they are required to compare, evaluate, and draw conclusions based on evidence found in the field. This directly supports the development of critical thinking indicators.

Table 4. Results of Hypothesis Testing of Critical Thinking Skills (CTS)

Testing	Test Statistics	Sig.	Decision
Paired Samples T- Test (Experiment)	t = -5.594	<0.001	H_0 Rejected
Wilcoxon Signed Rank Test (Control)	Z = -3.330	<0.001	H_0 Rejected
Mann -Whitney U Test (Posttest)	U = 102,000	0.217	H_0 Accepted

Paired test results The Samples T- Test in the experimental class showed a significance value of less than 0.001, which means there was a significant increase in critical thinking skills after the implementation of the Tumpek Wariga -based PjBL model. Meanwhile, the results of the Wilcoxon Signed Rank Tests on the control class also showed significant improvement. However, the improvement in the experimental class was greater than in the control class.

Although the results of the Mann -Whitney U Test showed no significant difference between the posttest scores of the two classes (Sig. = 0.217), the posttest average and mean scores the experimental class rank remained higher than the control class. This indicates that the Tumpek Wariga -based PjBL model tends to yield better results for critical thinking skills, although the relatively small sample size means the difference is not yet statistically significant.

Tumpek Wariga local wisdom also makes a significant contribution to improving critical thinking skills. Through environmental observation and exploration activities related to Montong durian cultivation practices in

the Tumpek Wariga tradition, students gain authentic and contextual learning experiences. These experiences enable them to connect science concepts to the realities of their daily lives, thus enhancing their thinking processes.

This finding is reinforced by the experimental class' N-Gain value of 0.35, which is in the moderate category and more than double that of the control class at 0.16. These results support the research of Wahyudi et al. (2025) which states that the implementation of the ethnoscience-based PjBL model is able to improve critical thinking skills, although its influence often requires a longer intervention period to produce an effect. large size.

Table 5. Descriptive Statistics of Collaboration Skills

Descriptive Statistics	Experimental Class	Control Class
Number of Students	17	16
The highest score (%)	93.75	60.42
Lowest Value (%)	75.00	39.58
Average (%)	83.58	51.56
Standard Deviation	5,556	6,298

The average collaborative skills of students in the experimental class reached 83.58%, while in the control class it was only 51.56%. The difference between the two reached 32.02 percentage points. The highest score of the experimental class was 93.75%, much higher than the highest score of the control class which was only 60.42%. Even the lowest score in the experimental class (75.00%) was still higher than the highest score of the control class. These results indicate that students who learn using the PjBL model based on Tumpek Wariga have the ability to work together, communicate, share tasks, and solve group problems much better than students in the control class.

Table 6. Results of the Comparison Test of Collaboration Skills

Class	N	Mean	Elementary School
Experiment	17	83,578	5,555
Control	16	51,563	6,298

t	df	Sig. (2-tailed)	Mean Difference
15,510	31	<0.001	32,015

The results showed that the average collaborative skills of the experimental class reached 83.58%, while the control class only achieved 51.56%. The difference of 32.02 points indicates a very significant difference between the two groups. The results of the Independent Samples T- Test also showed a significance value of less than 0.001, so it can be concluded that the PjBL

model based on Tumpek Wariga has a significant effect on students' collaborative skills.

The high level of collaboration skills in the experimental class occurred because all stages of the PjBL required students to work in groups to design projects, divide tasks, conduct field observations, discuss, and present project results. This process fosters communication, cooperation, responsibility, and collective decision-making skills. Furthermore, the values embodied in the Tri Hita Karana philosophy of the Tumpek Wariga tradition also strengthen the collaboration process. The Pawongan value, which emphasizes harmonious relationships between people, encourages students to help each other, respect the opinions of others, and take responsibility for group assignments. Therefore, learning not only results in improved academic abilities but also strengthens students' social character.

Vygotsky's theory which emphasizes the importance of social interaction in knowledge formation through the Zone of Proximal Development (ZPD). Furthermore, Dinda and Sukma (2021) explain that PjBL is a learning model that naturally develops collaboration skills because students must exchange ideas, solve problems together, and produce products collectively. These findings are also supported by research by Fitri et al. (2024), Lumbu et al. (2024), Sari et al. (2023), and Arjaya et al. (2024), which found that ethnoscience- based learning significantly improves students' collaboration skills through contextual and meaningful learning activities.

Table 7. Recapitulation of the Effectiveness of the PjBL Model Based on Tumpek Wariga

Effectiveness Indicators	Experimental Class	Control Class	Information
KBK Pretest Average	66.76	68.00	Equivalent
KBK Posttest Average	77.82	73.06	Higher ex.
Average N-Gain KBK	0.35	0.16	Ex. more than 2×
N-Gain Category	Currently	Low	Different categories
Effect KBK Size	0.38	–	Small
Average Collaboration (%)	83.58	51.56	Difference of 32.02 points
Effect Collaboration Size	5,402	–	Very large

Based on the results of the effectiveness analysis, the Tumpek Wariga -based PjBL model proved to be more effective than conventional

learning in improving students' critical thinking and collaboration skills. For critical thinking skills, the average N-Gain of the experimental class was 0.35 (medium category), while the control class was only 0.16 (low category). The effect value, the size of 0.38 indicates that the model has a real influence even though it is still in the small category.

Tumpek Wariga local wisdom provides an important contribution to improving critical thinking skills. Through environmental observation and exploration activities related to the Montong durian cultivation practice in the Tumpek Wariga tradition, students gain authentic and contextual learning experiences. These experiences enable students to connect science concepts with the realities they encounter in their daily lives, thus making the thinking process more meaningful. This is reinforced by the N-Gain value of the experimental class of 0.35, which is categorized as moderate and more than double that of the control class of 0.16. These results support the research of Wahyudi et al. (2025) which states that the implementation of the ethnoscience- based PjBL model can improve critical thinking skills, although its influence often requires a longer intervention period to produce an effect large size.

Meanwhile, in collaboration skills, the effect value obtained was the size was 5,402, which is considered very large. This finding indicates that the Tumpek Wariga -based PjBL model has a much stronger impact on collaboration skills than critical thinking skills.

Overall, the research results demonstrate that the Tumpek Wariga -based PjBL model positively impacts students' critical thinking and collaboration skills. However, the magnitude of the impact on these two variables differs. The impact on collaboration skills is significantly greater than on critical thinking skills. This finding suggests that social skills develop more rapidly through collaborative project activities, while critical thinking skills require more time to develop optimally.

These results align with research by Gonzalez -Perez and Ramirez-Montoya (2022), which explains that critical thinking skills require a longer development process because they are related to higher-level cognitive processes. Conversely, collaboration skills can develop more quickly when

students are intensively involved in structured social activities. This finding is also supported by research by Fitri et al. (2024), which found a very strong relationship between critical thinking skills and collaboration skills (r = 0.938), suggesting that increased collaboration during learning also supports the improvement of students' critical thinking abilities.

D. Kesimpulan

The Tumpek Wariga-based Project-Based Learning (PjBL) model had a positive effect on students' critical thinking skills. This was indicated by the increase in the experimental group's mean critical thinking score from 66.76 to 77.82, with an N-Gain score of 0.35 (moderate category), which was higher than that of the control group with an N-Gain score of 0.16 (low category). The results of the Paired Samples T-Test revealed a significant improvement in the experimental group ($t = -5.594$; $p < 0.001$). Furthermore, the effect size value of 0.38 indicated that the Tumpek Wariga-based PjBL model had a measurable effect on students' critical thinking skills, although the magnitude of the effect was categorized as small.

The Tumpek Wariga-based Project-Based Learning (PjBL) model also had a highly significant effect on students' collaboration skills. The average collaboration score of the experimental group reached 83.58% (very high category), whereas the control group achieved only 51.56% (moderate category). The Independent Samples T-Test demonstrated a highly significant difference between the two groups ($t = 15.510$; $p < 0.001$). In addition, the effect size value of 5.402 was classified as very large, indicating that the implementation of the Tumpek Wariga-based PjBL model was highly effective in enhancing students' collaboration skills.

Overall, the Tumpek Wariga-based PjBL model was effective in simultaneously improving students' critical thinking and collaboration skills. The integration of PjBL syntax with the ethnoscientific context of Tumpek Wariga created a contextual, meaningful, and student-centered learning environment. This approach not only encouraged students to think critically in understanding and solving problems related to their local environment and culture but also fostered teamwork, communication,

and responsibility in completing group projects. Therefore, the Tumpek Wariga-based PjBL model can serve as an effective instructional alternative for developing twenty-first-century skills among elementary school students.

The researcher recommends implementing the Project Based Learning (PjBL) model based on Tumpek Wariga as an alternative instructional approach, as it has been proven effective in improving students' critical thinking and collaboration skills. Future researchers are encouraged to apply this model to different learning materials, educational levels, and longer research durations in order to obtain a more comprehensive understanding of the effectiveness of local wisdom-based learning.

DAFTAR PUSTAKA

Ardianti, S. D., & Raida, S. A. (2022). The effect of ethnoscience-based project-based learning on science concept mastery. *Jurnal Pendidikan IPA Indonesia, 11*(1), 45–55.

Arfida, S., Hidayah, R., & Wahyudi, T. (2024). Integrating local wisdom into science learning: Bridging traditional knowledge and formal education. *Journal of Science Education Research, 8*(2), 112–125.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Creswell, J. W. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Thousand Oaks, CA: Sage Publications.

Daulay, M., & Asrizal, A. (2024). Development of ethnoscience-based learning materials on local cultural context. *Jurnal Pendidikan Sains, 12*(1), 33–47.

Dinda, F., & Sukma, E. (2021). Project-based learning as a strategy to develop collaborative and creative skills. *Jurnal Inovasi Pendidikan, 5*(2), 90–102.

Elfrida, S., Syukri, M., & Halim, A. (2023). Development of ethnoscience-based PjBL with performance assessment to improve critical thinking skills. *Jurnal Pendidikan Biologi Indonesia, 9*(2), 55–68.

Facione, P. A. (1994). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction*. Millbrae, CA: California Academic Press.

Fairus, R., Rahman, A., & Susilo, H. (2024). Local wisdom integration in primary science learning: Student motivation and engagement outcomes. *Asia Pacific Education Review, 25*(1), 88–101.

Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). London, England: Sage Publications.

Fitri, D., Halim, A., & Syukri, M. (2024). The effect of ethnoscience inquiry learning on critical thinking and collaboration skills in physics

education. *Jurnal Fisika Pendidikan, 6*(1), 14–28.

Gde, I. M., Suarni, N. K., & Artini, L. P. (2023). Ethnoscience-based project learning for environmental literacy development. *Jurnal Pendidikan Lingkungan, 4*(2), 45–58.

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of education 4.0 in 21st century skills frameworks. *Sustainability, 14*(3), 1493. doi:10.3390/su14031493

Hake, R. R. (1999). *Analyzing change/gain scores*. Paper presented at the American Educational Research Association Division D, Measurement and Research Methodology.

Hermawan, R., Suherman, A., & Ruswandi, U. (2017). Collaboration rubric based on IRA standards for 21st-century learning assessment. *Jurnal Penelitian Pendidikan, 9*(2), 77–89.

Hikmawati, H., Sutrio, S., & Momentum, M. (2020). Critical thinking skills in science education: Assessment and ethnoscience integration. *Jurnal Pijar MIPA, 15*(4), 381–392.

Lumbu, A., Yohanita, A. M., & Damopolii, I. (2024). Integration of Oro Kino-Kino traditional games from Sentani Papua in physics learning: Stimulating collaboration skills and learning outcomes. *Jurnal Etnomatematika, 3*(1), 20–35.

Marzuki, M., & Natsir, M. (2021). Characteristics and implementation of project-based learning in 21st-century education. *Jurnal Ilmiah Mandala Education, 7*(1), 120–132.

Mirwanda, A., Rahayu, S., & Fajaroh, F. (2024). Innovation in science teaching: Bridging conventional methods with 21st-century approaches. *Jurnal Pendidikan IPA Indonesia, 13*(2), 145–158.

Mulyani, S., Hernani, H., & Rustaman, N. Y. (2021). Science education in the era of industrial revolution 4.0: Challenges and opportunities. *Jurnal Pendidikan IPA Indonesia, 10*(1), 1–12.

Munira, R., Sulistyo, G. H., & Irawati, S. (2024). Ethnoscience integration in elementary education: Enhancing scientific literacy and cultural awareness. *Jurnal Pendidikan Dasar Nusantara, 9*(2), 88–102.

Nurcahyani, N., Sudarmin, S., & Ridlo, S. (2021). Implementation of ethnoscience in science education: Improving scientific literacy. *Jurnal Ilmu Pendidikan, 27*(1), 45–56.

Rahim, A., Mustari, M., & Gunawan, G. (2022). Local culture in science learning: Its effects on motivation and participation. *Jurnal Pendidikan Sains Sosial, 4*(1), 22–35.

Sagala, R., Umam, R., Thahir, A., Saregar, A., & Wardani, I. (2019). The effectiveness of STEM-based on gender differences: The impact of physics concept understanding. *European Journal of Educational Research, 8*(3), 753–761. doi:10.12973/eu-jer.8.3.753

Sari, D. K., Sudarmin, S., & Pamelasari, S. D. (2023). Ethnoscience in science curriculum: Evidence from Indonesian elementary classrooms. *Jurnal Ilmiah Pendidikan Dasar, 10*(2), 88–100.

Septina, N. (2024). Review of ethnoscience applications in Indonesian science education:

Gaps and research directions. *Jurnal Riset Pendidikan IPA, 2*(1), 10–22.

Setiawan, A., Malik, A., Suhandi, A., & Permanasari, A. (2021). Effect of STEM-based project laboratory on the improvement of students' creative thinking skills. *Journal of Physics: Conference Series, 1157*(3). doi:10.1088/1742-6596/1157/3/032010

Shenkoya, T., & Kim, E. (2023). Sustainability in higher education: Critical thinking and collaborative skills for 21st-century learners. *Sustainability, 15*(2), 1412. doi:10.3390/su15021412

Shofyana, D., Susilo, H., & Suwono, H. (2022). Challenges in project-based learning implementation: Social and cultural dimension. *Jurnal Inovasi Kurikulum, 19*(2), 89–103.

Sholahuddin, A., Khairunnisa, K., & Sauqina, S. (2021). The role of contextual teaching in bridging science concepts with students' lived experiences. *Jurnal Pendidikan IPA Indonesia, 10*(3), 355–367.

Sugiyono. (2019). *Metode penelitian kuantitatif, kualitatif, dan R&D*. Bandung, Indonesia: Alfabeta.

Supriani, N. K., Artini, L. P., & Padmadewi, N. N. (2025). Implementation of Tri Hita Karana values in Balinese-Hindu community agricultural practices. *Jurnal Kajian Bali, 15*(1), 100–118.

Swariga, I. M., Suastika, I. K., & Sudiarta, I. G. P. (2024). Application of Tri Hita Karana local wisdom in school environment as Balinese cultural tourism preservation. *Jurnal Ilmu Sosial dan Humaniora, 13*(2), 245–258.

Tikhonova, E., & Raitskaya, L. (2023). Academic skills for the 21st century: Rethinking collaboration and critical thinking in higher education. *Journal of Language and Education, 9*(1), 4–17. doi:10.17323/jle.2023.16300

Wahyudi, T., Sudarmin, S., & Nuswowati, M. (2025). Duration effects in ethnoscience PjBL: Implications for critical thinking development. *Jurnal Riset Pendidikan Sains, 3*(1), 44–59.

Wahyuni, N. L. P. S., Suarjana, I. M., & Renda, N. T. (2023). Tumpek Wariga ceremony as a medium for ecological knowledge transmission in Balinese-Hindu culture. *Jurnal Kajian Budaya Bali, 5*(1), 30–44.

Yani, A. (2021). *Pembelajaran berbasis proyek: Konsep dan implementasi*. Jakarta, Indonesia: Pustaka Cendekia.