



Ethnoscience-based discovery learning for enhancing scientific literacy of preservice primary school teachers

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ABSTRACT

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This study proposed and tested an ethnoscience-based discovery learning model to enhance the scientific literacy of preservice primary school teachers in a science practicum course. The study used an instructional design based on Plomp's model, which comprised four stages of instructional design: preliminary analysis, prototype development, formative evaluation, and implementation testing. Expert validation, a small-group trial ($n = 20$), the main implementation ($n = 57$), and limited dissemination ($n = 34$) were used. This model consists of six learning phases: stimulation, formulation of the problem, data collection, culturally scientific processing, verification, and generalization. Some examples of learning tools were a model book, semester lesson plan, lecturer book, student book, multimedia, learning media, and a scientific literacy assessment instrument. Expert validation was conducted using a questionnaire, with a high validity value of 3.91. Practicality improved from 3.59 in the first trial to 3.96 after formative revision. Scientific literacy outcomes showed consistent improvement across phases, with normalized gain values ranging from 0.67 to 0.74. A paired-samples t-test confirmed significant within-group improvement in the main implementation phase, $t(56) = 53.24$, $p < .001$, Cohen's $d_z = 7.05$. Findings suggest that ethnoscience integration within discovery learning can function as an epistemic bridge between local knowledge and scientific concepts. The model shows potential for preservice teacher education, particularly in strengthening contextual inquiry and evidence-based reasoning. However, because no control group was used, the results should be interpreted as developmental and implementation-based evidence rather than causal superiority.

Contribution/Originality: This study contributes to the existing literature by developing an ethnoscience-based discovery learning model, originating a cultural-scientific processing phase, investigating structural ethnoscience integration, providing systematic cultural-scientific analysis, finding consistent scientific literacy improvement, and documenting iterative development, validation, implementation, formative revision, and limited dissemination among pre-service primary teachers.

1. INTRODUCTION

Scientific literacy goes beyond just knowing science content. The learner needs to be able to explain phenomena, critically analyze evidence, interpret data, and reason scientifically in decision-making. For preservice teachers of primary schools, their scientific reasoning competence has a double objective – they have to be able to reason scientifically themselves as well as design science activities based on evidence for children (DeBoer, 2000; Fives, Huebner, Birnbaum, & Nicolich, 2014; Gormally, Brickman, & Lutz, 2012; Norris & Phillips, 2003). This is still

relevant in the context of Indonesia. According to PISA 2022, Indonesia's science score was 383, indicating that there is still much trouble using science to solve real problems (OECD, 2023).

The initial analysis showed that projects and cases were used in the science practicum; however, there were still numerous tasks to complete. The students developed their work and reports but failed to create scientific problems, provide evidence, and link the cultural knowledge to the science topics. A conceptual structure was required in the course to facilitate scientific investigations and turn the cultural knowledge into scientific research. The Guided Discovery Method provides a theoretical structure for such learning. It includes observation, questioning, data collection, testing of hypotheses, and generalization of concepts. In cases of too little guidance, learners become frustrated and engage in pointless exercises. Much research evidence exists that validates scaffolding, sequencing, feedback, worksheet exercises, and evaluation criteria (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Furtak, Seidel, Iverson, & Briggs, 2012; Hmelo-Silver, Duncan, & Chinn, 2007; Kirschner, Sweller, & Clark, 2006; Lazonder & Harmsen, 2016; Mayer, 2004).

Ethnoscience provides another culturally relevant source of phenomena, vocabulary, technology, and communal explanations. Its utility lies in the way it is used. If local knowledge is used merely as an illustration, it would only serve a decorative purpose. However, when the students compare it to observations, literature, experiments, and scientific concepts, it will become an epistemic resource for exploration (Aikenhead & Ogawa, 2007; Bang & Medin, 2010; Snively & Corsiglia, 2001). Ethnoscience of North Sumatran palm sap processing was chosen because it allowed exploration of topics such as substances, mixtures, fermentation, physical and chemical changes, equipment, and processes involved. This research created a model of ethnoscience-embedded discovery learning for pre-service primary school teachers.

It consists of a culture-scientific processing component during which students transform community knowledge into evidence-based scientific explanations. Four research questions were formulated: (1) How can ethnoscience and discovery learning be combined in one model? (2) How reliable are the proposed model and its accompanying resources? (3) How usable is the model after repeated improvements? (4) Is there any developmental evidence that the level of scientific literacy improves with the use of the model? In contrast to previous research, in which a medium or resource was usually developed without an instructional model (Ahied, Muharrami, Fikriyah, & Rosidi, 2020; Nida, 2021), the present study aims to fill that gap.

2. LITERATURE REVIEW

2.1. *Scientific Literacy in Preservice Teacher Education*

Literacy in science includes knowledge of concepts along with epistemic and social practices. Students need to know science concepts, but at the same time need to be able to assess the quality of evidence, justify claims, make sense of representations, and provide explanations. In this way, the broadened notion connects literacy assessment to argumentation, modeling, and evidence-based explanations (Driver, Newton, & Osborne, 2000; Duschl, 2008; Fives et al., 2014; Gormally et al., 2012; Schwarz et al., 2009). Various instructional strategies give more weight to various aspects of literacy skills. A content-oriented approach is good for developing terminology and factual knowledge but does not imply the investigation of claims by students. An inquiry approach gives more possibilities for working with evidence, although classroom inquiry can turn into procedures related to laboratory work (Chinn & Malhotra, 2002; Sandoval & Reiser, 2004; Windschitl, Thompson, & Braaten, 2008). A socioscientific approach develops decision-making and informal reasoning, but not the ways of examining and reconstructing local cultural knowledge (Sadler, 2004; Sadler & Zeidler, 2005).

The limitation of ethnoscience and culturally relevant science education is associated with their consideration of community knowledge as a source of learning. This limitation becomes evident in situations when culture is considered merely as an example, illustration, or even a stimulus to motivate. In such conditions, students can become interested in the context without testing the explanation and translating it into scientific terms (Aikenhead & Jegede,

1999; Aikenhead & Ogawa, 2007; Bang & Medin, 2010; Brown, 2017). Future primary school teachers require an approach that would incorporate both approaches' strong points. They will have to develop scientific reasoning, learn how to modify curriculum materials for themselves, and acquire skills in inquiry-oriented instruction. Teacher education should demonstrate how to choose a local phenomenon, create a researchable question, guide the collection of evidence, and evaluate the explanation (Crawford, 2007; Forbes & Davis, 2010; Menon & Sadler, 2016). Scientific literacy in the current research is seen as a result of combined efforts in conceptual, epistemic, and pedagogic spheres. Guided discovery serves as an inquiry process. Ethnoscience is used as a source of culturally grounded phenomena. Cultural-scientific processing becomes the required epistemic translation process. These components create the theoretical core of the suggested model and differentiate it from other approaches.

2.2. Guided Discovery Learning and Inquiry

Guided discovery is most justified. Unaided discovery presupposes that the learner will be able to recognize significant variables and procedures and construct relationships between concepts on their own. Reviews and meta-analyses have shown that this expectation is often unfounded. Prompting, feedback, structure, and scaffolding help to enhance conceptual understanding and inquiry skills (Alfieri et al., 2011; Furtak et al., 2012; Hmelo-Silver et al., 2007; Kirschner et al., 2006; Lazonder & Harmsen, 2016). This is why the developed model rejects unguided discovery. Each step includes a certain task: stimulation involves identification of a cultural phenomenon; problem statement transforms observations into researchable questions; data gathering entails collection of evidence; cultural-scientific processing includes comparison of community and scientific explanations; verification includes testing of adequacy claims; and generalization entails transfer of the concept.

In contrast to other inquiry frameworks, this framework contributes two things here. One contribution lies in its ability to identify where cultural knowledge fits into the inquiry cycle and how it should be assessed. The other contribution lies in the fact that the framework provides the complete support network for preservice teachers who need to see examples of doing all those things in action to conduct the inquiry themselves (Appleton & Kindt, 2002; Crawford, 2000; Davis, Petish, & Smithey, 2006; Sizer, Tharp, Wrigley, Al-Bataineh, & Park, 2021).

2.3. Ethnoscience and Cultural-Scientific Processing

Ethnoscience involves how societies perceive, categorize, employ, and understand nature. It serves in science education to assist students in navigating the space between informal and formal knowledge without considering one as a replacement for the other. The place-based and culturally responsive work that has been done highlights the benefits of such navigation, where evidence and conceptuality remain important criteria (Aikenhead & Ogawa, 2007; Bang & Medin, 2010; Barnhardt & Oscar Kawagley, 2005; Semken & Freeman, 2008; Snively & Corsiglia, 2001).

The cultural-scientific processing phase responds to the main weakness of context-only ethnoscience activities. Students must document the local explanation, identify observable evidence, compare it with scientific concepts, explain agreements or differences, and produce a defensible conclusion. This phase is the model's main novelty because it turns local practice from background context into an object of epistemic analysis and links it directly to scientific literacy.

3. METHODOLOGY

3.1. Research Design and Participants

The current research employed design research for instruction derived from the model of Plomp, which entails the stages of preliminary investigation, prototyping, formative evaluation, and implementation (Plomp & Nieveen, 2013; van den Akker, 1999). This particular design was chosen since the immediate objective was to develop and improve an instructional model and its associated tools incrementally. Since this was a developmental phase in

research, there was no use of a control group, as different sets of participants acted as prototypes rather than equivalent experimental conditions.

The pilot phase studied the science practical courses, students' needs, existing teaching materials, and the ethnoscientific knowledge of North Sumatra. The prototyping phase yielded an initial draft for a textbook, lesson plans for one semester, guidebooks for lecturers, student books, worksheets, media, learning aids, and assessment tools. After expert judgment and testing by small groups, the full-scale implementation followed. But first, there was a limited phase of dissemination to see whether the model was still applicable elsewhere. The purposive sampling method was employed since participants were part of the desired science practicum courses. The small-group experiment ($n = 20$) and main implementation ($n = 57$) were conducted in the study program of education for elementary school teachers (PGSD), Faculty of Teacher Education, Universitas Muhammadiyah Sumatera Utara, Medan, Indonesia, in the 2025/2026 academic year. Limited diffusion comprised 34 participants in the program of education for Islamic elementary teachers (PGMI), Universitas Islam Negeri Ar-Raniry, Banda Aceh, Indonesia. These samples represented different levels of development and should not be considered equivalent groups. The archival data sample did not have information on age and gender; hence, there is no verified information about them.

3.2. Instruments and Implementation Procedure

Instruments utilized include the expert validation sheet, practicality and model implementation sheets, the lecturer and students' questionnaires, and the scientific literacy essay test consisting of 12 questions. The validation of the instrument involved the theory of validation, syntax, social system, reaction principle, support system, expected results, learning environment, management actions, and evaluation of the learning process. Four dimensions existed for the scientific literacy essay test, including explanation of scientific phenomena, design of scientific investigations, evaluation of scientific investigation and evidence, and interpretation of scientific evidence and data. For the format of the instrument, refer to Appendix A. The scientific literacy essay test was analyzed through the use of an analytical rubric involving conceptually correct and relevant evidence, quality reasoning, and scientific explanations. Two independent observers observed the classroom implementation to evaluate interobserver reliability.

Score sheets of the independent second rater for the essay were lacking; hence, the inter-rater reliability of the essay results was not obtained. This is an aspect that lowers confidence in measurement and cannot be compensated for by internal consistency or interobserver agreement. Thus, results from the essay were carefully interpreted and validated with expert opinion, implementation observations, feedback from the lecturers and students, and the dissemination process. Future research work should keep scores from at least two independent raters and obtain agreement before resolving differences. The process of implementation consisted of six stages. First, the students would study the local cultural phenomenon using methods such as fieldwork, demonstration, or the media in an anonymous manner. They would then develop scientific problems and collect evidence by means of observations, interviews, literature, and simple experiments. The local practices would then be transformed into scientific ideas through cultural-scientific processing.

3.3. Data Analysis and Ethical Considerations

The validity and practicality scores were analyzed descriptively through the use of means. Change in scientific literacy was numerically determined using the normalized gain, which was computed by subtracting the pre-test score from the post-test score, then dividing it by the maximum score minus the pre-test score (Hake, 1998). Through inference, pre-test and post-test scores in large-group testing were compared using a paired-samples t-test after the normality of the paired differences was checked using the Shapiro–Wilk test. This analysis will provide the mean difference, 95% confidence interval, and Cohen's d_z to assess the magnitude of change (Lakens, 2013; Sullivan & Feinn, 2012). The inter-rater reliability of observation scores was analyzed using the two-way random-effects

absolute-agreement intraclass correlation coefficient (ICC[A,1]) because two raters scored the continuous observations (Hallgren, 2012; Koo & Li, 2016).

Paired-sample analysis is used to measure changes in the main implementation group. Still, it is not possible to separate the model's effect from factors like maturation, repeated testing, pretest sensitivity, how instruction and tests are matched, and other related variables. Because of this, the results are reported as developmental implementation data. To compare effectiveness, a quasi-experimental or randomized study with a proper control group is needed. The institutions gave this study the green light. Everyone who took part knew exactly what they were signing up for. Nobody was forced; every bit of data was stripped of names before we even started looking at it.

4. RESULTS

4.1. Ethnoscience Reconstruction and Model Syntax

The development process reconstructed North Sumatran palm sap processing into scientific concepts and learning activities. Culture was not treated as a decorative element but as a starting point for questioning, observing, testing, and explaining phenomena. Table 1 presents the main reconstruction of local practices into scientific concepts and preservice teacher learning tasks.

Table 1. Reconstruction of ethnoscience practices into scientific learning tasks.

Ethnoscience practice	Related science concepts	Learning task in the model
Observation of palm sap harvesting and local terminology	Observation, classification, natural resources, and ecological context	Students record cultural terms, observable phenomena, and initial scientific questions.
Use of bamboo ladders and harvesting procedures	Simple technology, safety, tools, and procedural investigation	Students identify the logic of local technology and connect it to procedural scientific inquiry.
Use of raru bark or additives in sap processing	Substances, mixtures, material interaction, and change in properties	Students compare local explanations with scientific explanations of changes in substances and mixtures.
Transformation of palm sap into derivative products	Physical change, chemical change, fermentation, and evidence-based explanation	Students interpret changes using evidence from observation, literature, and simple experiments.

The reconstruction was conceived as part of six discovery learning phases. There was relatively little change in the basic structure of the processing stage in culture and science, which was identified as the main modification. It required students to convert local ways of thinking and doing into scientific ways of thinking and doing. Table 2 depicts the syntax of the model developed.

Table 2. Syntax of the ethnoscience-based discovery learning model.

Phase	Main learning activity	Integrated ethnoscience focus
Stimulation	Students observe local cultural phenomena through videos, photographs, demonstrations, or field documentation and record initial questions.	Local wisdom, indigenous knowledge, local terminology, natural resources, and ecological systems.
Problem statement	Students formulate scientific problems based on observed cultural practices and connect them to science topics.	Scientific concepts embedded in cultural practices.
Data collection	Students collect data through observation, interviews, literature study, documentation, and simple experiments.	Traditional technology and indigenous classification systems.
Cultural-scientific processing	Students reconstruct indigenous knowledge into scientific concepts related to substances, mixtures, physical changes, chemical changes, and scientific procedures.	Local procedures, traditional technologies, indigenous classification systems, and cultural practices.

Phase	Main learning activity	Integrated ethnoscience focus
Verification	Students examine evidence, compare findings with scientific theory, and evaluate the validity of their explanations.	Local procedures, traditional technologies, and indigenous classification systems.
Generalization	Students formulate conclusions and apply the scientific principles learned to other cultural or everyday contexts.	Local wisdom, indigenous knowledge, local terminology, natural resources, and ecological systems.

The syntax presented in Table 2 keeps intact all key features of guided discovery learning but adds a cultural-scientific processing stage to the process. The stimulation, problem statement, and data-gathering stages make it possible for students to discover scientific problems in relation to the observed local practices. The cultural-scientific processing stage calls upon the students to compare the local explanation with the scientific concept before verification and generalization.

Within this scheme, ethnoscience is used as both the motivating factor and the source of phenomena to be investigated and explained using scientific knowledge. Figure 1 shows how all the elements relate to one another. This design is a synthesis of science practicum learning, scientific literacy, discovery learning, ethnoscience, and instructional modeling. The quality of the model is to be evaluated in terms of its validity, practicality, and effectiveness. Therefore, the analysis here treats the product as the whole instructional system.

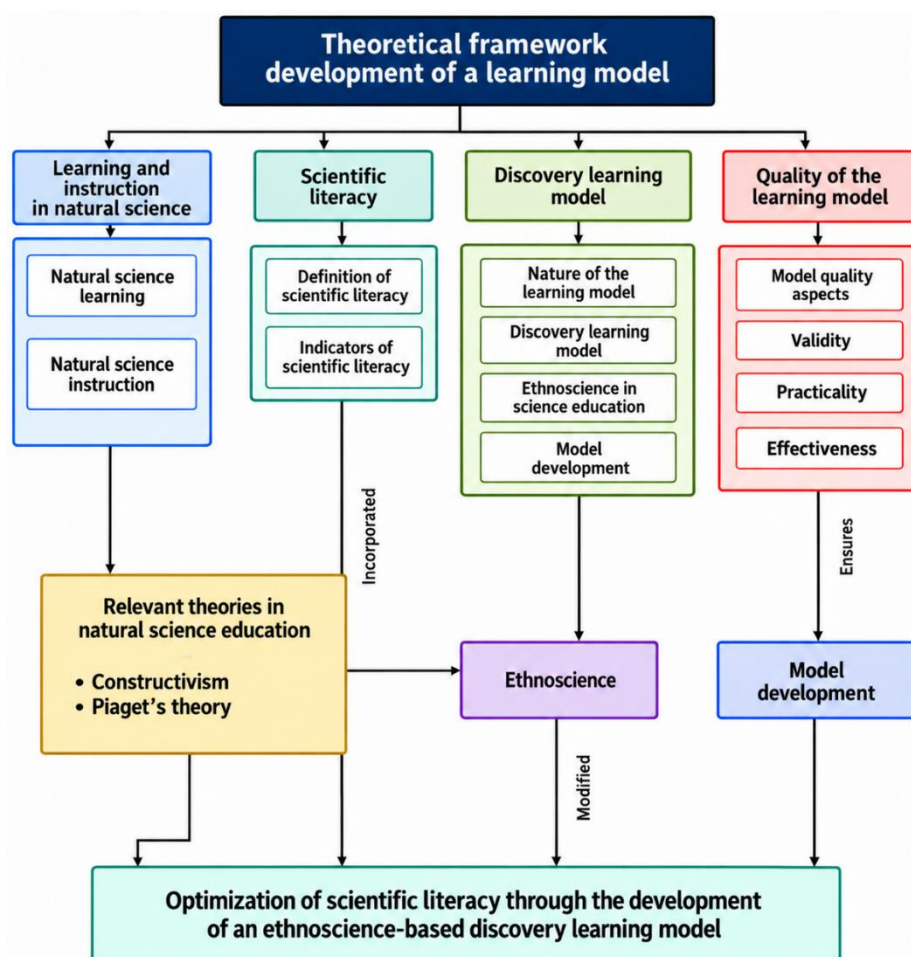


Figure 1. Theoretical framework for developing the ethnoscience-based discovery learning model.

Figure 2 presents non-identifying documentation of the palm sap-processing context used as ethnoscientific learning material in the developed model.



Figure 2. Non-identifying documentation of the ethnoscientific context of palm sap processing.

4.2. Validity, Practicality, and Reliability of the Model

The model developed, along with its instructional products, passed through the validation process to ensure the validity of the criteria. The mean scores of the model book according to the design and language experts were 3.90 and 3.92, respectively. The course learning plan scored 3.85 and 3.98 according to the structural expert and model effectiveness expert. The lecturer guide and student book were found to be valid in terms of content but required a little revision in terms of design. The student worksheets scored the highest, i.e., 4.00, and the learning media scored 3.74. The overall mean score was 3.91. Table 3 presents the validation results for the developed model and its instructional products across the evaluated components.

Table 3. Summary of model and instructional product validation results.

Component evaluated	Mean score	Interpretation
Model book - design expert	3.90	Valid with minor revision
Model book - language expert	3.92	Valid with minor revision
Course learning plan - structural expert	3.85	Valid with minor revision
Course learning plan - model effectiveness expert	3.98	Valid
Lecturer guide - materials	3.91	Valid
Lecturer guide - design	3.68	Valid with minor revision
Student book - materials	3.91	Valid
Student book - design	3.68	Valid with minor revision
Student worksheets	4.00	Valid
Learning media	3.74	Valid with minor revision
Overall mean	3.91	Valid

The practicality improved after the formative revisions. The first trial produced a mean practicality score of 3.59, with several problems identified during implementation. These included a lack of sufficient time for all steps, inadequate use of learning materials, ambiguous criteria for assessing the group tasks, a lack of technology in the worksheets, and unclear directions for evaluation. The revision involved the form book, worksheets, assessment directions, layout, and schedule. After that, the mean practicality score rose to 3.96. Interobserver reliability was high during the main implementation: $ICC(A,1) = .920$, 95% bootstrap CI $[0.858, 0.951]$; average-measures ICC was 0.958.

4.3. Scientific Literacy Improvement

Improvement in scientific literacy was determined by using the pre-test and post-test scores of each participant. In the small-group experiment, the mean score on the pre-test was 17.63 (SD = 2.17). The mean score on the post-test was 73.17 (SD = 3.73), and this generated a mean normalized gain of 0.67. On the other hand, in the large-group experiment, the mean score on the pre-test was 23.00 (SD = 8.60). The mean score on the post-test was 77.69 (SD = 3.43), giving a mean normalized gain of 0.71. In the dissemination stage, the mean pre-test score was 26.42 (SD =

5.13), while the mean post-test score was 81.40 (SD = 4.85), giving a mean normalized gain of 0.74. Table 4 presents the pre-test and post-test scores and mean normalized gains across the three study phases.

Table 4. Summary of scientific literacy improvement and implementation evidence.

Phase	N	Pre-test M (SD)	Post-test M (SD)	Mean N-gain
Trial I - small group	20	17.63 (2.17)	73.17 (3.73)	0.67
Trial II - large group	57	23.00 (8.60)	77.69 (3.43)	0.71
Dissemination	34	26.42 (5.13)	81.40 (4.85)	0.74

There was improvement in implementation evidence throughout all study phases. For instance, in the first trial, practicality had a score of 3.59, with 45.00% good classroom activity and a student response score of 55.92%. In the second trial, after revision, there were 87.72% good classroom activities, with lecturer response and student response scores of 97.13 and 94.30, respectively. The third stage, which involved the dissemination phase, had 85.29% good classroom activities. The distribution of large-group paired-difference scores was approximately normal, as indicated by the results of the Shapiro-Wilk test ($W = 0.959$, $p = 0.051$). This allowed us to apply a paired-samples t-test at the 0.05 significance level. Results from the t-test indicated a significant increase in scientific literacy, $t(56) = 53.24$, $p < 0.001$, mean difference = 54.69, 95% CI [52.64, 56.75], Cohen's $d_z = 7.05$. The model appears to be quite effective, but we cannot claim causality in its use because there is no control group. Table 5 presents the statistical assumptions, within-group comparison, and reliability checks used to support the interpretation of these findings.

Table 5. Statistical assumptions and reliability checks.

Check	Data source	Result	Interpretation
Normality of paired difference scores	Large-group pre-test and post-test scores ($n = 57$)	Shapiro-Wilk $W = 0.959$, $p = 0.051$	Difference scores approximated normality at $\alpha = .05$; paired t-test was retained.
Paired-samples comparison	Large-group pre-test and post-test scores ($n = 57$)	$t(56) = 53.24$, $p < 0.001$, 95% CI [52.64, 56.75], Cohen's $d_z = 7.05$	Very large within-group improvement; no evidence of causal superiority without a control group.
Interobserver reliability	Large-group observation scores from two observers ($n = 57$)	ICC(A,1) = 0.920; 95% bootstrap CI [0.858, 0.951]; average-measures ICC = 0.958	Excellent absolute agreement between observers.
Essay scoring reliability	Scientific literacy essay item scores	Independent double-rater essay scores were not available; $\alpha = 0.920$ for pre-test and $\alpha = .641$ for post-test	Interrater reliability could not be computed; double scoring is recommended in future studies.

There are design limitations, and the lack of a control may not support an assumption of causality. Achievement of coherence, usability, and promise in each iteration of the product is the primary question in instructional design research. To make better causal inferences, a comparison is needed with conventional discovery learning, inquiry-based learning, or other contextual science learning models conducted as a quasi-experimental or randomized study.

4.4. Formative Participant and Classroom Evidence

The audiotaped interviews were not data sources or part of the data sources. Themes of the interviews and personal quotations are not, therefore, included in the manuscript, but the participants' evidence that was uncovered in the form of formative comments and observed classroom behavior. Some comments in the small-group trial indicated three concerns among the students: (1) time constraints to complete all phases, (2) lack of full utilization of learning tools, and (3) unclear group-project scoring. Feedback from the lecturer indicated that evaluation tools were not very user-friendly and that worksheets should include feedback on how technology was used. Before the main

trial, these points were taken into account for changes to the implementation schedule, worksheets, project rubric, and lecturer guidance.

The revised implementation observed that students generated their own hypotheses rooted in the culture, gathered and compared evidence, made links between their communities and formal science concepts, checked their explanations during discussions with peers in groups, and presented conclusions at the end of classes regarding queries posed by their peers. The mean activity score for the classrooms increased from 2.91 for the small-group trial to 3.92 for the main implementation. The student response rate rose from 55.92 to 94.30, and that of the lecturers rose from 67.03 to 97.13. The process evidence shows that there has been some correlation between improvements in statistics and the evidence of implementation, and the effort to make implementation more transparent with the appearance of actual participation in the statistics.

5. DISCUSSION

The result revealed that scientific literacy enriches the formation of students through an ethnoscience approach based on a discovery learning model that involves cultural experiences, systematic inquiry, and structured learning materials. The model expands on the traditional discovery learning model by incorporating a cultural-scientific processing stage. An important point is that local knowledge is not to be used as an example to introduce the lesson, but students should research the functions of local knowledge and the logic of local practices and then think about how to provide a scientific explanation for them. This approach is aligned with evidence supporting guided inquiry and discovery learning, in which the child receives support through structure in the formulation of a problem, the collection of evidence, interpretation of evidence, and drawing conclusions (Alfieri et al., 2011; Furtak et al., 2012; Hmelo-Silver et al., 2007; Lazonder & Harmsen, 2016; Mayer, 2004; Pedaste et al., 2015). Whereas this requirement of epistemic translation between Indigenous knowledge systems and formal scientific concepts distinguishes this model, the two converge in the clear integration of cultural-scientific processing.

The ethnoscientific context of the processing of palm sap served as a tangible key in raising enquiries, gathering evidence, and checking one's explanations. Familiar community practices led the students to come to understand concepts such as substances, mixtures, physical change, chemical change, and procedural inquiry. This outcome can support the arguments throughout cross-cultural and place-based science education that local practices can provide good bridges between everyday and formal scientific understanding (Aikenhead & Jegede, 1999; Aikenhead & Ogawa, 2007; Bang & Medin, 2010; Semken & Freeman, 2008; Snively & Corsiglia, 2001). An increase in practicality was noted as something that was brought about by some design changes and not by score reporting alone. In the first trial, students asked for more optimal time management, more complete pedagogical use of learning tools, and more transparent scoring of group projects. Lecturers were looking for better guides on assessment, better technology incorporation, and easier evaluation. The following revisions were made for better classroom implementation and greater positive responses in the second trial. The importance of prototype use for subsequent improvement and development in accordance with DBR principles (Anderson & Shattuck, 2012; Barab & Squire, 2004; Cobb, Confrey, DiSessa, Lehrer, & Schauble, 2003; Design-Based Research Collective, 2003; Wang & Hannafin, 2005) is reflected here.

It is clear from the normalized gains and paired-samples results that there is significant improvement within the groups. The effect size is, however, very large, which means that careful attention must be paid to its value. The effect size may have been overstated because of low pre-test scores, multiple exposure to the identical measure of literacy, a direct connection between the intervention and the literacy assessment, and the absence of a comparison group. The results in this study lend support to the implementation of this model in the context studied but are unable to confirm that this model is better than traditional discovery learning, research-based learning, or other context-based learning. Not much was known about the scoring of essays. Inconsistency among items measured on the post-test was somewhat suboptimal, and an independent double rater was not available. There is no substitute for inter-rater

reliability on the primary outcome; the analytic rubric and evidence used in the assessment support transparency. Areas for further research are weak items, agreement established through the use of two independent raters, agreement at the item level, and agreement-resolution processes. If possible, distinguish between people educating and marking and people analyzing and drawing conclusions from the results.

Through this research, the author added an informative model that contains instructional syntax, social system, reaction principles, supporting instruments, learning media, and assessment instruments so as to allow the students to carry out learning at the highest level. In the preservice environment, the cultural-scientific processing phase is pedagogically relevant since the students are getting ready to be cultural bridge designers. This helps children's experiences with location connect to formal scientific ideas. This fits into the construct of culturally responsive teacher education, which views the cultural backgrounds, community knowledge, and relevant contexts as primary tools that can be used in the learning process in school (Aronson & Laughter, 2016; Gay, 2002; Ladson-Billings, 1995; Morrison, Robbins, & Rose, 2008). But there are a number of aspects of scientific literacy that could be improved. Students need more chances to explain scientific phenomena using correct scientific language and to make inferences about scientific information and evidence in a more analytical way. Going forward, scientific argumentation and the use of data, the evaluation of data, and written explanation should be addressed more strongly. Rationalizing claims and reasoning about issues of social relevance are critical elements, as is systematic analysis of evidence; these are essential for enhancing scientific literacy (Gormally et al., 2012; Sadler, 2004; Sadler & Zeidler, 2005).

6. CONCLUSION

The study was conducted to create an ethnoscience-based discovery learning model that can improve the scientific literacy of pre-service primary school teachers. The model was valid and feasible and demonstrated potential for within-group improvement in the context of implementation. The overall mean score (3.91) for the expert validation showed that the instrument was valid. The first-trial practicality score was 3.59, and the practicality score improved to 3.96 after formative revision.

The mean normalized gains were calculated based on the individual scores to be 0.67, 0.71, and 0.74 for the small-group trial, large-group implementation, and dissemination phase, respectively. The model mainly comprises the cultural-scientific processing phase, which helps students convert local cultural knowledge into scientific explanations. Teachers use this phase to provide lots of context, help students make meaning, and make science learning culturally responsive. The model proposed here presents a new educational perspective toward teacher-training practicum classes, particularly in terms of teaching goals that focus on science education, cultural integration, cooperation, and the use of evidence.

The one-group pre-test and post-test design, the restricted sample of teacher education, and the single primary context of ethnoscientific explanations are limitations of this study. It is not possible to infer superior causal effects from the results without a randomized or matched comparison group. Scores for independent double ratings were not available. Post-test internal consistency was slight. The high within-group effect could be because of high exposure to the assessment, reduction of baseline scores, and the corresponding nature of the intervention and assessment.

The study was limited to providing qualitative evidence in terms of aggregated written feedback and structured observation instead of recorded interviews. Studies need to be conducted to compare this model with traditional discovery or inquiry learning in the near future. They should also reflect the involvement of a diversity of institutions and cultural contexts, as well as assess retention rates and transfer pathways to teaching practice and offer an extensive inter-rater reliability data set. Thus, the present results must be seen as a validation of the viability and implementation of a model that appears to be promising.

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Informed Consent Statement: Informed verbal consent was obtained from all participants, and all data were anonymized to protect participant confidentiality.

Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.

Competing Interests: The authors declare that they have no competing interests.

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Appendix A. Source-Aligned Instrument and Rubric Summary.

This appendix summarizes the actual instrument structure used in the study. The appendix was revised to align with the original dissertation instruments: the effectiveness/observation instrument, lecturer response questionnaire, student response questionnaire, scientific literacy test blueprint, and scientific literacy scoring rubric. The wording below is presented in English for manuscript transparency, while the original instruments were prepared in Indonesian.

A.1. Instrument Set Used in the Study.

Instrument	Function	Response format / main dimensions
Expert validation sheets	Model book, learning tools, teaching materials, worksheets, media, and assessment instruments	Four-point expert judgement scale; components include feasibility, presentation, language, layout, syntax, social system, reaction principles, supporting system, and expected effects.
Effectiveness/classroom activity observation sheet	Implementation of the ethnoscience-based discovery learning model during classroom activities	Four-point scale: 4 = very appropriate / very good / very effective; 3 = appropriate / good / effective; 2 = less appropriate / less good / less effective; 1 = inappropriate / poor / ineffective.
Lecturer response questionnaire	Lecturer judgement of implementation practicality	Four-point scale from very poor to very good; 15 items covering clarity of course plan instructions, competency achievement, student response, and implementation difficulty.
Student response questionnaire	Student perception of the model and learning tools	Four response categories: strongly agree, agree, less agree, and disagree; 12 items covering clarity of course devices, implementation of the model, and evaluation of the ethnoscience-based model.
Scientific literacy essay test	Pre-test and post-test scientific literacy assessment	Twelve essay items mapped to four aspects and six indicators of scientific literacy. Scores were converted to a 0-100 scale for analysis.

A.2 Scientific Literacy Essay Test Blueprint

The scientific literacy test consisted of 12 essay items. The item blueprint followed four aspects of scientific literacy and six operational indicators.

Scientific literacy aspect	Indicator	Item type	Item numbers
Explaining scientific phenomena	Explain a scientific phenomenon accurately based on scientific knowledge.	Essay	1, 3
Explaining scientific phenomena	Make an accurate prediction from a scientific phenomenon.	Essay	2, 4
Designing scientific investigation	Understand the elements of scientific investigation design.	Essay	5, 7
Evaluating scientific investigation	Analyze investigation data and its impact on findings or conclusions.	Essay	6, 8
Interpreting scientific data and evidence	Interpret data and draw appropriate conclusions.	Essay	9, 12
Interpreting scientific data and evidence	Make decisions based on scientific data and evidence.	Essay	10, 11

A.3 Essay Item Contexts and Prompts

The essay prompts used ethnoscientific and everyday contexts. The following English translations summarize the original item contexts and tasks:

1. Klepon: Explain what happens when rice flour clumps and is combined with melted palm sugar during klepon preparation.
2. Tuak: Explain whether pure substances and mixtures in tuak strongly influence tuak production.
3. Getuk: Predict what happens when additives are processed together with other ingredients during getuk preparation.
4. Coffee: Predict what happens when convection heat transfer involves the movement of an intermediary substance in coffee preparation.
5. Taman Lubuk Pakam: Explain, based on scientific processes, why fruit statues such as pineapple, durian, and salak are used as icons in the park.
6. Taman Sawah: Explain why the raised trapezium-shaped huts in the rice-field park are designed that way based on local knowledge and scientific knowledge.

7. Palm sap / nira: Analyze why one-night and several-night fermentation of palm sap differ in color, aroma, and alcohol content, and explain the consequences.
8. Coffee beans: Analyze why male coffee beans have higher selling prices than ordinary coffee beans and how male and female beans can be distinguished.
9. Klepon coloring: Interpret findings from comparing natural pandan extract and pandan essence in klepon, especially taste and color attractiveness.
10. Getuk processing: Compare manual stone pounding and processing with an ampia tool, then relate the differences in texture and taste to science concepts.
11. Palm sap / nira: Decide what should be done to obtain a large quantity of palm sap based on evidence and practical knowledge.
12. Coffee waste: Decide how coffee peel waste can be reused to increase its value.

A.4 Analytic Scoring Rubric for Scientific Literacy Essay Responses

The source rubric used a 1-10 scoring range. Higher scores indicate more complete, scientifically grounded, and understandable responses. The rubric bands are summarized below.

Score range	Rubric description
9-10	Response is very complete, meets the relevant indicator(s), includes scientific elements, and is very easy to understand.
7-8	Response is understandable but misses one relevant scientific-literacy indicator.
5-6	Response is partly understandable but misses two relevant scientific-literacy indicators.
3-4	Response is difficult to understand and misses almost all relevant scientific-literacy indicators.
1-2	Response does not meet the relevant scientific-literacy indicators and is very difficult to understand.

A.5 Lecturer Response Questionnaire

The lecturer response questionnaire contained 15 items scored on a four-point scale: 1 = very poor, 2 = poor, 3 = good, and 4 = very good. The items were organized into four dimensions:

Dimension	Items	Content covered
Clarity of course plan instructions	Items 1-4	Clarity of course learning outcomes, lesson-plan steps, model components, and assessment system.
Achievement of competencies and learning objectives	Items 5-9	Support for preservice teachers' scientific literacy, curiosity, critical thinking, concept maps, worksheet use, and technology integration.
Student response during implementation	Items 10-12	Student enthusiasm, motivation, and enjoyment in using the learning model.
Implementation difficulty	Items 13-15	Ease of implementing the syntax, using the course tool set, and using learning evaluation tools.

A.6 Student Response Questionnaire

The student response questionnaire contained 12 items with four response categories: strongly agree, agree, less agree, and disagree. The questionnaire was organized into three dimensions:

Dimension	Items	Content covered
Clarity of course devices	Items 1-4	Clarity of learning outcomes, model steps in the course plan, learning objectives and time allocation, and assessment system.
Model implementation in learning	Items 5-9	Support for scientific literacy, curiosity, critical thinking, worksheet activities, technology integration, and ease of using the learning tool set.
Evaluation of the ethnoscience-based model	Items 10-12	Interest in the learning process, project motivation, and suitability of the model for other course materials.

A.7 Observation and Model-Implementation Components

The observation instruments covered both classroom activity and implementation quality. The classroom activity sheet included lecturer activity and student response during learning, whereas the model-implementation sheet focused on syntax, social system, and reaction principles.

Component	Observed content
Lecturer classroom activity	Opening, objectives, apperception, motivation, material delivery, model syntax, media/resources, reinforcement, time management, task organization, assessment, closing, and follow-up.
Student response and learning achievement	Usefulness for scientific literacy, enjoyment, confidence, active participation, and achievement of learning outcomes.
Model syntax implementation	Stimulation, problem statement, data collection, cultural-scientific processing, verification, and generalization.
Social system	Active participation, democratic discussion, educative interaction, group discussion, cooperation, peer response, and freedom to explore literacy based on experience and theme.
Reaction principles	Facilitation, individual/pair/group learning, responses to questions and opinions, scaffolding, guidance, and motivation.

A.8 Use of Instrument Evidence for Revision

Validation sheets, lecturer and student response questionnaires, and observation data were used formatively. Feedback and score patterns were used to revise the model book, semester lesson plans, lecturer guide, student book, worksheets, learning media, implementation instructions, and assessment instruments before the large-group implementation and dissemination phase.

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