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A framework for building scientific literacy through an inquiry learning model using an ethnoscience approach

Yatin Mulyono [1,*], Sapuadi Sapuadi [2], Yuliarti Yuliarti [3], Suhailee Sohnui [4]

[1]*Department of Science Education, IAIN Palangka Raya, Palangkaraya, Indonesia*
[2]*Department of Tarbiyah, IAIN Palangka Raya, Palangkaraya, Indonesia*
[3]*Department of Information Systems, STMIK Palangka Raya, Palangkaraya, Indonesia*
[4]*Department of Oriental Languages, Chiang Mai University, Chiang Mai, Thailand*

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A B S T R A C T

Scientific literacy is an essential skill in today's complex information age, particularly in 21st-century education. The inquiry-based learning model, which encourages students to actively engage in research, has been shown to effectively improve scientific literacy. However, combining this model with an ethnoscience approach, which links scientific learning to local cultural knowledge, is important for creating a more comprehensive and relevant learning experience. This study aims to combine the strengths of these two methods to develop a framework for an inquiry-based learning model that incorporates an ethnoscience approach. Through a review of existing literature, the study finds that integrating ethnoscience into inquiry-based learning can enhance student engagement, relevance, and learning impact. The proposed model consists of five key components: Syntax, principles of reaction, social systems, support systems, and instructional effects and follow-up. This approach has shown significant positive effects in adult education, helping students understand science while valuing local cultural knowledge. By fully utilizing the potential of inquiry-based learning, ethnoscience approaches, and scientific literacy, we can create a more inclusive, relevant learning environment that promotes students' overall development.

1. Introduction

In the midst of increasingly widespread and complex information flows in the 21st century, scientific literacy has become a skill that is not only important but also vital for students (Kinskey and Zeidler, 2021; Sari et al., 2023; Zulfiani et al., 2023). The ability to understand, analyze, and evaluate scientific information is no longer just an additional need but a necessity that underpins future success and resilience. Scientific literacy is not just about mastering scientific facts but also about understanding the scientific process itself (Maass et al., 2019). Students who have scientific literacy are able to see the world critically, identify reliable sources of information, and differentiate between facts and opinions (Sharon and Baram-Tsabari, 2020). They have the ability to ask questions, seek answers, and test hypotheses using systematic scientific methods (Chen, 2023). In the 21st century era, which is filled with global challenges such as climate change, health crises, and rapid technological change, scientific literacy skills are becoming increasingly important. Students who have strong scientific literacy can act as agents of change and develop innovative solutions to complex problems facing the world today.

The usefulness of scientific literacy for the future of students is not limited to the scientific field alone (Dye, 2023). The ability to think critically, solve problems, and communicate effectively are skills that are highly valued in many career fields (Palines and Cruz, 2021). With strong scientific literacy, students can become visionary leaders, creative innovators, and responsible global citizens (Budiarti and Tanta, 2021; Palines and Cruz, 2021). Therefore, learning in the current era must be designed to facilitate increasing students' scientific literacy. The curriculum should include instruction that promotes understanding of scientific concepts, use of evidence,

* Corresponding Author.
Email Address: yatin.mulyono@iain-palangkaraya.ac.id (Y. Mulyono)
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Corresponding author's ORCID profile:
https://orcid.org/0000-0002-4148-9119

and development of critical thinking skills. Teachers also need to be equipped with adequate training to facilitate learning that builds strong scientific literacy in students. By prioritizing scientific literacy in education, we not only prepare future generations to face complex challenges but also open the door to the enormous potential contained in scientific knowledge and understanding.

In exploring the scientific world, the inquiry learning model has emerged as one of the most effective strategies for increasing students' scientific literacy (Putri et al., 2021; Schwartz et al., 2023; Suwono et al., 2023). Not just presenting information to students, the inquiry model encourages them to become true researchers who are actively involved in the process of exploration, discovery, and problem-solving (Großmann and Wilde, 2019; Nieswandt et al., 2020). The advantages of the inquiry model in improving students' scientific literacy skills are very diverse. First of all, this model encourages students to ask questions. By stimulating curiosity and asking relevant questions, students deepen their understanding of scientific concepts (Wen et al., 2020). Furthermore, the inquiry model develops critical and analytical thinking skills (Li and Yuan, 2022). Through experimentation, observation, and data analysis, students learn to evaluate information carefully and make conclusions based on available evidence.

However, the success of the inquiry learning model does not only depend on its application in the classroom (Muskita et al., 2020; Nieswandt et al., 2020). It is important to realize that meaningful learning occurs when students can relate scientific concepts to their daily lives. Without a direct connection to a real context, inquiry learning can lose its relevance for students (Qamariyah et al., 2021). Therefore, the implementation of the inquiry model needs to be linked to the local culture and knowledge where students live. This approach is known as ethnoscience, in which scientific learning is integrated with the student's cultural and environmental context. By linking scientific concepts to local traditions, beliefs, and knowledge, students can gain a deeper and more relevant understanding.

The integration of ethnoscience in science learning also brings many benefits (Sotero et al., 2020; Winarto et al., 2022). Apart from strengthening students' cultural identity, it also increases their interest in science by showing its relevance in everyday life (Sari et al., 2023; Sotero et al., 2020). In addition, this approach also respects and enriches local cultural heritage, making science learning a vehicle for promoting diversity and inclusion. Thus, implementing an effective inquiry learning model not only requires a deep understanding of science but also sensitivity to the cultural context and locality of students. Through the integration of ethnoscience, science learning can become more meaningful, relevant, and enriching for all students. This research aims to develop a framework for an inquiry learning model using an ethnoscience approach and explore new paths that combine the advantages of these two approaches to increase students' scientific literacy. In the journey to find the most effective learning model, this research examines in depth how the integration of ethnoscience in an inquiry model can produce engaging, relevant, and meaningful learning experiences for students. By focusing on an inquiry approach, this research explores how this model can stimulate students' curiosity and activeness in the science learning process. Through experiments, observations, and field research, researchers examined the effectiveness of various strategies and methods in creating a learning environment that supports the development of students' scientific literacy. However, what makes this research stand out is its unique approach to integrating ethnoscience into a model of inquiry. By incorporating cultural context, local traditions, and community knowledge into the science learning process, this research creates a more holistic and relevant framework for students. This integration is not only about linking scientific concepts to students' daily lives but also respecting and enriching their cultural heritage.

This research makes an important contribution to advancing science, particularly in science education and learning. It introduces new perspectives on making science learning more inclusive, respectful, and empowering for all students, regardless of their cultural background. Additionally, it provides both theoretical and practical support for educators to develop learning strategies that promote scientific literacy through a more comprehensive approach. Moreover, this research advances theory and research methods in science education by incorporating an inquiry-based approach enhanced with ethnoscience. This encourages fresh thinking and practices in science learning that are academically relevant and beneficial to students' real-life experiences. Overall, the study presents a new framework for inquiry-based learning and opens up opportunities for further discoveries that can enrich education and science as a whole.

2. Method

2.1. Research approach

This research adopts a qualitative approach, which provides space for an in-depth understanding of the phenomenon under study. This approach allows researchers to explore the complexity and context of the concepts being studied, as well as to understand how interactions between these concepts can shape the learning experience.

2.2. Research design

The research design used in this research is a literature study with in-depth analysis. Through this method, researchers searched for literature related to the theory and characteristics of andragogy, inquiry learning, ethnoscience, scientific literacy, and their respective relationships. After the literature was found, the researcher carried out a careful and in-depth analysis to understand the implications and application of these theories in the context of this research.

2.3. Research stages

This research went through 3 stages, namely (1) literature search, (2) literature selection, and (3) in-depth analysis. A literature search at the initial stage of this research was carried out involving a search for literature related to the theories that were the focus of the research, namely andragogy, inquiry learning, ethnoscience, and scientific literacy. Searches were carried out through academic databases, scientific journals, books, and other trusted sources. The literature selection stage is after relevant literature is found, and the researcher selects the literature based on certain criteria, such as quality, relevance, and newness of the information. The selected literature will be the basis for in-depth analysis in this research. The final stage is an in-depth analysis. The main stage of the research is an in-depth analysis of the selected literature. Researchers carefully examine and analyze the contents of each piece of literature, looking for relationships between the theories studied and their respective characteristics. This analysis helps researchers understand the implications and application of these theories in the research context.

2.4. Analysis instruments and procedures

The instrument used in this research is a literature review consisting of journal articles, books, and other scientific sources. The analysis procedure involves reading and understanding each piece of literature, identifying key concepts, and comparing the theories studied. Analysis is carried out systematically and structured to ensure accuracy and depth of understanding.

2.5. Validity and reliability

Quality control measures were implemented to ensure the validity and reliability of the research. This includes the literature selection process, careful and detailed analysis, and the use of trusted sources. In addition, methodological transparency and conformity between findings and existing literature are also a focus in ensuring research quality.

2.6. Research limitations

The limitation of this research lies in its focus on literature that is relevant to the theories studied. This research does not involve field research or primary data collection but concentrates on the analysis of existing literature. Apart from that, time constraints and accessibility to literature were also taken into consideration in this research.

3. Results and discussion

In creating an inclusive and in-depth learning environment, the construct of an inquiry learning model with an ethnoscience approach offers a rich and structured approach. Inspired by the theory of Joyce and Calhoun (2024), this model summarizes the key elements that form the basis of an effective, learner-oriented learning process. The learning model framework construct consists of (1) syntax, (2) reaction principles, (3) social system, (4) support system, and (5) instructional impact and accompanying impact.

Syntax is a structured learning procedure. The syntax in this learning model includes a series of steps or procedures that direct learning. This includes initial setup, formulating research questions, planning an experiment or investigation, collecting data, analyzing results, and summarizing findings. By providing a clear structure, syntax helps students understand the steps that must be followed in the inquiry process. The reaction principle is responsive to the context and needs of students. The reaction principle emphasizes the importance of responsiveness to learners' needs, interests, and context. In the context of ethnoscience, this means considering students' cultural knowledge, traditions, and local experiences in designing learning. By being responsive to students' contexts, learning becomes more relevant, interesting, and meaningful for them. The social system is collaboration and interaction between students. The social system in this model underlines the importance of collaboration and interaction between students in learning. Through discussion, group work, and sharing ideas, students can support each other, expand their understanding, and build knowledge together. This creates an inclusive learning environment and promotes active learning. The support system supports students in the learning process. The support system includes everything that supports and complements the learning process. This includes resources, reading materials, technology, and guidance from teachers or facilitators. By providing adequate support, students feel more confident in carrying out the inquiry process and overcoming obstacles they may face. The instructional and accompanying impact is an evaluation and reflection on learning. The instructional and accompanying impact reflects the importance of evaluation and reflection on the learning that has been carried out. This involves assessing student progress and the effectiveness of learning strategies, as well as reflecting on the overall learning experience. By conducting regular evaluations and reflections, teachers and students can identify areas that need improvement and improve their learning process. By paying attention to these five constructs, the inquiry learning model with an ethnoscience approach provides a comprehensive and student-oriented framework. Through this approach, learning becomes more relevant, inclusive, and enriching for all students, which is in line with the goals of inclusive and sustainable education. The construction of the learning model framework is shown in Fig. 1.

Construct	Inquiry	Characteristics of Ethnoscience	Inquiry Learning Model with an
Theory	[1] observation [2] manipulation [3] generalization [4] verification [5] application	[1] local knowledge [2] cultural integration [3] interaction between students [4] basic competencies [5] interaction process [6] learning tools [7] freedom to learn	Andragogy theory
Objective			Improving scientific literacy abilities
Utility			Meeting the needs of learning problems related to the need to develop valid, effective and practical learning models in improving scientific literacy abilities
Syntax			[1] cultural and local knowledge integration orientation [2] formulating the problem [3] formulate a hypothesis [4] collecting data [5] testing the hypothesis [6] formulate culture-integration conclusions
Management Class Room			[1] reaction principle [2] social system [3] support system [4] impact
Tools			[1] semester program plan [2] teaching material [3] student worksheet [4] assessment instrument

Fig. 1: Construction of an inquiry learning model using an ethnoscience approach

The syntax of the learning model is the result of theoretical synthesis from inquiry syntax, which is integrated with the characteristics of ethnoscience. The synthesis of inquiry syntax and its relationship with scientific literacy indicators is shown in Fig. 2.

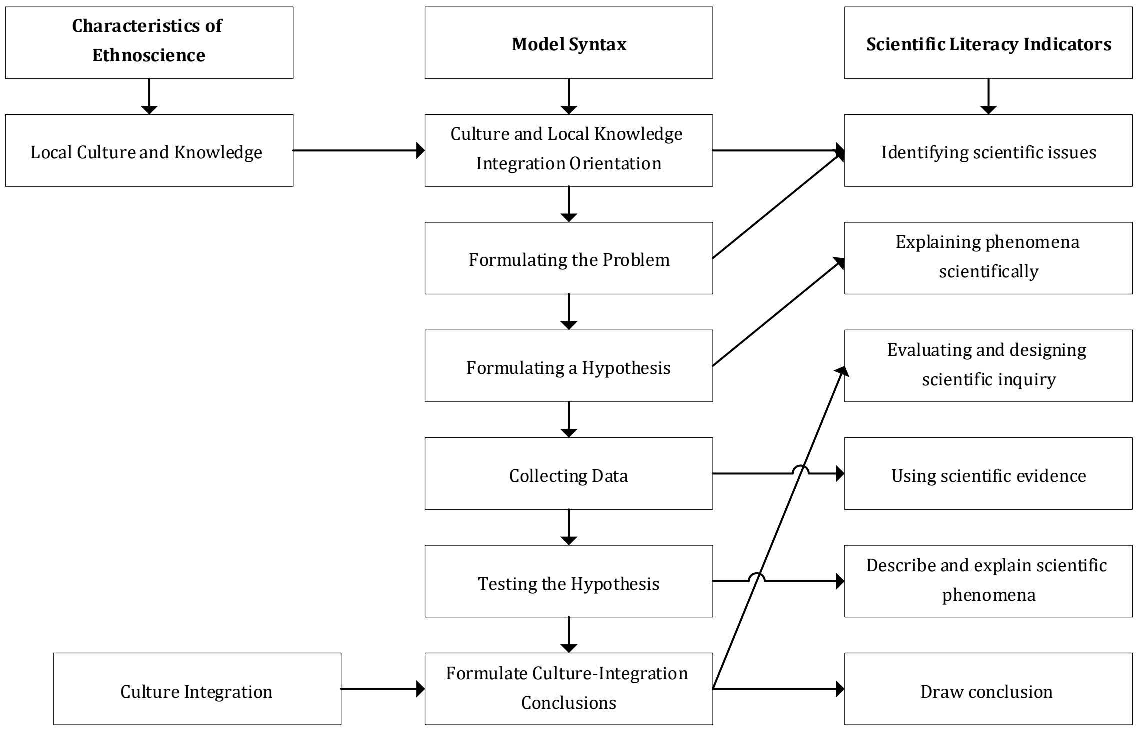

Fig. 2: Syntax of the inquiry learning model syntax and its relationship with scientific literacy indicators

The inquiry-based learning model with an ethnoscience approach has undergone a rigorous validation process by seven experts using the Delphi technique. The Delphi technique is a systematic method for obtaining assessments from experts through a series of questionnaires with controlled feedback. The experts in this validation have relevant backgrounds and high competence in education, science, and culture. Based on calculations using the Aiken formula, the validation results indicate that the inquiry-based learning model with an ethnoscience approach has a high level of validity. All components and aspects evaluated received scores indicating that this model is valid and feasible to implement in an educational context. Therefore, this learning model can be implemented with confidence that it will positively contribute to the learning process, especially in integrating cultural and scientific elements into teaching and learning activities.

The world of education is a laboratory where knowledge and understanding are continuously explored, and in the classroom, inquiry learning models play a central role in stimulating curiosity and discovery (Li and Yuan, 2022; Yuliarti et al., 2023). Behind the greatness of the inquiry learning model is a simple but powerful philosophy: Learning is a process of exploration (Qamariyah et al., 2021; Verawati et al., 2021). This model encourages students to become active researchers in the search for knowledge, exploring questions, developing hypotheses, conducting experiments, and evaluating the results (Murphy et al., 2021). It is a journey of discovery, where the teacher is not the primary source of knowledge but a facilitator who supports and guides students on their journey.

The inquiry learning model has the characteristics: (1) active involvement, (2) questions as a leader, (3) critical involvement, (4) collaboration, (5) independence, and (6) connection to the real world (Hinostroza et al., 2024; Dah et al., 2024). The inquiry model requires active participation from students (Jong, 2023; Wu, 2023). They don't just listen to lectures or read books but are directly involved in the learning process through experimentation, observation, and research (Nzomo et al., 2023; Radu et al., 2023). Questions are the center of inquiry learning. Students are invited to ask questions, identify problems, and formulate hypotheses (Kavanagh et al., 2024). This encourages them to think critically and creatively (Mulyono et al., 2023). Students are invited to evaluate evidence, summarize results, and make conclusions based on the data collected. This helps them develop critical and analytical thinking skills (Kwangmuang et al., 2021). Collaboration is key in inquiry learning. Students work together in groups to test their ideas, share discoveries, and solve problems together (Nieswandt et al., 2020). It strengthens teamwork skills and communication abilities. The inquiry model provides space for students to take control of their own learning (Suwono et al., 2023; Zeng et al., 2024). They learn to manage time, plan experiments, and evaluate results independently. Inquiry learning is more than just looking for answers (Radu et al., 2023; Schwartz et al., 2023). It links scientific concepts to real-world contexts, demonstrating the relevance and practical application of the knowledge gained. The inquiry learning model is not just about transferring knowledge from teacher to student but about opening the door to exploration, discovery, and deep understanding (Hinostroza et al., 2024; Nzomo et al., 2023). With active involvement, leading questions, and critical engagement, the inquiry model shapes students into true researchers who are ready to face challenges in the real world (Hu et al., 2024; Kavanagh et al., 2024). By building independence, collaboration, and connection to the real world, inquiry is not just a learning model but a learning philosophy that supports overall student growth.

In education, it is important to combine basic ideas from inquiry learning models, ethnoscience approaches, and scientific literacy skills. This is particularly true when viewed through the lens of andragogy theory, which focuses on learning that is centered on adult learners (Ates and Aktamis, 2024; Nieswandt et al., 2020). The inquiry learning model encourages active knowledge (Fathali, 2024; Li and Yuan, 2022). The inquiry learning model places students as active subjects in the learning process. It is a concept that bases itself on the philosophy that the best learning occurs when students have control over their own learning (Arslan et al., 2023; Murphy et al., 2021). In the context of andragogy, where adult learners are considered to have unique motivations and experiences, the inquiry model becomes very relevant (Agustini et al., 2023; Yeung et al., 2024). This allows them to build deep understanding through exploration, experimentation, and reflection in accordance with the principles of independent learning.

The framework of the inquiry learning model using an ethnoscience approach, as shown in Fig. 2, shows that the learning steps are able to facilitate an increase in scientific literacy indicators. The study by Koustourakis et al. (2020) highlighted the impact of family cultural activities on shaping students' cultural capital and educational expectations. The research emphasizes how students' everyday family cultural activities organize their expectations and orient them toward different educational pathways. That aligns with the task as it demonstrates the influence of cultural integration activities on students' predispositions, which can be linked to their ability to identify scientific problems. The ability to interpret data and evidence scientifically, as demonstrated by students in the mathematics education study program, can have a significant impact on their scientific literacy and problem-solving skills (Peni et al., 2022). That is in line with Pratiwi et al. (2019), who emphasized that such abilities can enhance students' liking for science, their capacity for scientific thinking, decision-making, and problem-solving, as well as their ability to identify public discourse and address challenges in the professional world. Therefore, the findings of this study support the notion that students' activities in cultural integration orientation and local knowledge formulation of problems can indeed enhance their ability to identify scientific problems.

Thompson and Skau (2023) explained that it offers insights into the scope of scientific hypotheses, emphasizing the importance of clarity and coherence in hypothesis formulation. The framework outlined in the reference can guide hypothesis-makers in articulating their hypotheses, linking results to existing knowledge, and explicitly defining the elements being tested. That directly speaks to the task by highlighting the critical relationship between formulating a hypothesis and explaining phenomena scientifically, as a well-constructed hypothesis serves as the foundation for scientifically explaining and testing phenomena. The study by Grooms et al. (2021) provided evidence of students' proficiency in integrating science content, practices, and crosscutting concepts to explain a phenomenon. That aligns with the task as it illustrates the relationship between formulating a hypothesis and explaining phenomena scientifically. The findings suggest that as students engage in the process of formulating hypotheses, they develop the proficiency to integrate scientific content and practices, which is essential for explaining phenomena scientifically.

The direct relationship between collecting data and using scientific evidence. By employing a data collection technique involving multiple-choice scientific literacy questions in the field of genetics, the study aimed to assess biology students' science literacy level. The utilization of the Program for International Student Assessment (PISA) questions as a data collection tool reflects the integration of scientific evidence into the assessment process, highlighting the essential link between collecting data and utilizing scientific evidence to evaluate students' scientific literacy. Therefore, the reference effectively speaks to the relationship between collecting data and using scientific evidence by showcasing the application of scientific literacy questions as a means of gathering and utilizing scientific evidence to assess students' understanding of genetic concepts (Hartono et al., 2023). The reference provided by Amala et al. (2023) aligned with the task of explaining the relationship between collecting data and using scientific evidence. The study's use of scientific literacy tests and interviews for data collection demonstrates the essential link between collecting empirical data and utilizing scientific evidence. By employing scientific literacy indicators and interviews, the study emphasizes the significance of gathering data rooted in scientific principles, which serves as the basis for deriving scientific evidence. Therefore, the reference effectively speaks to the relationship between collecting data and using scientific evidence by highlighting the reliance on empirical data to substantiate scientific claims and conclusions (Amala et al., 2023).

Rubin (2022) discussed the concept of "HARKing" (hypothesizing after the results are known) and its potential impact on scientific research. While the article may not directly address the relationship between testing hypotheses and describing/explaining scientific phenomena, it does touch upon the broader issue of questionable research practices and their implications for scientific replication and reliability. To effectively explain the relationship between testing hypotheses and describing/explaining scientific phenomena, a reference that directly addresses the process of testing hypotheses, analyzing data, and using scientific evidence to describe and explain natural phenomena would be more suitable. That would provide a more focused and relevant perspective on the scientific method and the role of hypothesis testing in advancing scientific understanding and explanation of phenomena. Therefore, while the reference provides insights into research practices, it may need to fully address the specific relationship between testing hypotheses and describing/explaining scientific phenomena.

Thompson and Skau's (2023) explanation offered valuable insights into the relationship between testing the hypothesis data and describing and explaining scientific phenomena. The framework outlined in the reference can guide hypothesis-makers in formulating their hypotheses by helping clarify what is being tested, linking results to previous known findings, and demarcating what is explicitly tested in the hypothesis. That highlights the critical role of hypothesis testing in the scientific process, as it provides a structured approach to gathering and analyzing data to evaluate the validity of the hypothesis and its implications for explaining scientific phenomena.

Zubrod et al. (2021) offered insights into the relationship between formulating culture-integrated conclusions, evaluating and designing scientific inquiry, and drawing conclusions, particularly in the context of linguistic complexity and its impact on famous trial outcomes. The study likely explores the role of language in culturally significant legal proceedings and how linguistic complexity may influence trial outcomes. By examining the influence of language on trial outcomes, the study may shed light on the process of formulating culture-integrated conclusions, evaluating and designing scientific inquiry, and drawing conclusions in the context of legal and cultural settings. The findings of the study may contribute to our understanding of how linguistic complexity shapes the outcomes of famous trials, providing valuable insights into the interplay between language, culture, and legal decision-making. That can inform the process of formulating culture-integrated conclusions by considering the linguistic and cultural factors that influence trial outcomes. Additionally, the study may offer methodological insights into evaluating and designing scientific inquiry in the context of legal and cultural research, highlighting the importance of considering linguistic complexity and cultural nuances in research design and analysis. Overall, the reference by Zubrod et al. (2021) may provide valuable insights into the relationship between formulating culture-integrated conclusions, evaluating and designing scientific inquiry, and drawing conclusions, particularly in the context of linguistic complexity and its impact on culturally significant legal proceedings.

The study by Fridman et al. (2020) provided valuable insights into the relationship between formulating culture-integrated conclusions, evaluating and designing scientific inquiry, and drawing conclusions, particularly in the context of preschoolers' nascent inquiry skills and metacognitive capabilities during scientific exploration tasks. The study aimed to examine the extent to which preschoolers implement inquiry skills, metacognitive awareness, and self-regulation capabilities during play-based scientific exploration and investigate the relationships between these capabilities. The findings of the study revealed that preschoolers exhibited inquiry capabilities, such as asking questions, planning, hypothesizing, using tools, and drawing conclusions, even without explicit goals and instructions. These capabilities were observed in both structured and open-ended exploration tasks, indicating that young children have the innate ability to engage in scientific inquiry and draw conclusions from their observations and experiences. Furthermore, the study identified significant correlations between preschoolers' inquiry capabilities and measures of metacognitive strategic awareness and self-regulation. That suggests that the development of inquiry skills and the ability to conclude scientific exploration are closely linked to metacognitive and self-regulation capabilities in young children. The iterative and cyclical nature of the entire process, as highlighted in the study, involves components of scientific inquiry such as designing experiments, evaluating evidence, and drawing inferences. This iterative process serves to form and revise theories about the phenomena under investigation, emphasizing the interconnectedness of formulating culture-integrated conclusions, evaluating and designing scientific inquiry, and drawing conclusions. Overall, the study by Fridman et al. (2020) underscored the importance of early science education experiences that encourage children to engage in structured exploration alongside play-based, open-ended exploration. It also highlights the fundamental relationship between inquiry skills, metacognitive capabilities, and the ability to conclude scientific exploration, contributing to a deeper understanding of the scientific inquiry process in young children.

The reference provided by Aristeidou and Herodotou (2020) offered valuable insights into the relationship between formulating culture-integrated conclusions, evaluating and designing scientific inquiry, and drawing conclusions. The study examines learning outcomes of citizens participating in online citizen science communities purposely designed for inquiry learning, with a focus on the 'Citizen inquiry' approach that prioritizes and scaffolds learning and engages people in all stages of the scientific process. The findings of the study indicate that participants engaged in the entire inquiry process, from forming a research question based on their everyday experience of science to concluding. That suggests that the design of the citizen science communities effectively facilitated participants' involvement in the scientific inquiry process, leading to the formulation of culture-integrated conclusions. The study highlights the importance of the design of online communities for science inquiries in shaping the learning outcomes of participants.

Furthermore, the differences in learning outcomes between the two design studies underscore the impact of the design on participants' understanding of research processes and methods, as well as their engagement in inquiry discussions and progress in scientific vocabulary. This emphasizes the critical role of evaluating and designing scientific inquiry in shaping the learning experiences and outcomes of participants in citizen science communities. Overall, the reference effectively illustrates the relationship between formulating culture-integrated conclusions, evaluating and designing scientific inquiry, and drawing conclusions by demonstrating how the design of online citizen science communities can influence participants' engagement in the entire inquiry process and contribute to the formulation of culture-integrated conclusions. The findings provide valuable considerations for science educators and citizen science facilitators to enhance the learning outcomes of citizen inquiry and similar online communities for science inquiries.

The study by Richter et al. (2022) provided insights into the relationship between formulating culture-integrated conclusions, evaluating and designing scientific inquiry, and drawing conclusions. While the study focuses on computer-assisted guided inquiry learning in the context of science education, the findings can be related to the broader process of formulating and drawing conclusions in scientific inquiry. In the context of the study, students engaged in computer-based direct instruction and computer-based inquiry learning, where they conducted virtual experiments and engaged in generative activities such as creating video explanations. The study aimed to compare the effectiveness of these instructional approaches in enhancing students' scientific problem-solving skills and conceptual understanding. The results of the study, contrary to the initial hypotheses, indicated that the direct instruction condition outperformed the inquiry learning conditions. However, moderation analyses revealed that the effectiveness of direct instruction was predominantly true for students with low levels of domain-specific self-concept. That suggests that the effectiveness of instructional approaches may depend on students' motivational prerequisites, such as their self-concept in the domain of study. In the broader context of scientific inquiry, the findings of the study highlight the importance of considering students' motivational and self-concept factors when evaluating and designing scientific inquiry activities. It underscores the need to tailor instructional strategies to enhance student's learning experiences and outcomes based on their individual characteristics and motivational factors.

Furthermore, the study emphasizes the role of formulating culture-integrated conclusions in the context of scientific inquiry. Drawing conclusions based on available evidence, testing hypotheses, and engaging in generative activities are essential components of scientific inquiry. The findings of the study contribute to a better understanding of the effects of different instructional approaches on students' learning and the factors that may influence the effectiveness of these approaches. Overall, the study by Richter et al. (2022) provided valuable insights into the relationship between formulating culture-integrated conclusions, evaluating and designing scientific inquiry, and drawing conclusions, particularly in the context of science education. It underscores the importance of considering students' motivational factors and self-concept in instructional design and the broader process of scientific inquiry.

The reference provided by Fernández et al. (2022) discussed students' performance in scientific skills during secondary education, particularly focusing on mathematics education, psychology, and existential meaning. The study highlights that students have difficulties in identifying problems, formulating hypotheses, drawing conclusions, and designing experiments. While the reference does not directly address the relationship between formulating culture-integrated conclusions and evaluating and designing scientific inquiry, it indirectly emphasizes the challenges students face in drawing conclusions and designing experiments, which are essential components of scientific inquiry. In the context of formulating culture-integrated conclusions, the ability to conclude scientific data and evidence is crucial for integrating cultural perspectives and insights into scientific findings. Additionally, evaluating and designing scientific inquiry involves the systematic assessment of research methods and the development of experimental designs to investigate scientific phenomena. These processes are essential for generating reliable and culturally relevant conclusions in scientific research. Therefore, while the reference does not explicitly address the relationship between formulating culture-integrated conclusions and evaluating and designing scientific inquiry, it indirectly underscores the importance of developing students' skills in drawing conclusions and designing experiments, which are integral to the broader process of formulating culturally integrated conclusions and conducting rigorous scientific inquiry.

The ethnoscience learning approach and the importance of scientific literacy skills emphasize key elements in higher education (Nurcahyani et al., 2021; Sari et al., 2023). These two concepts complement each other and are relevant in the learning context. The ethnoscience learning approach is about respecting, recognizing, and utilizing local wisdom and culture in the learning process (Putra, 2021; Yuliana et al., 2021). This brings awareness to the importance of local context in shaping scientific understanding. In an increasingly globalized world, there should be no impression that local knowledge does not have the same value as scientific knowledge. In contrast, the ethnoscientific approach emphasizes that traditional knowledge can be a strong foundation for understanding scientific concepts. For example, in indigenous communities, knowledge of medicinal plants can be the basis for understanding chemical concepts in modern medicine (Ardianti and Raida, 2022; Zidny and Eilks, 2022).

On the other hand, scientific literacy skills are the key to critical thinking in an era where knowledge and information are increasingly widespread (Dye, 2023; Palines and Cruz, 2021). Scientific literacy is not only about understanding scientific facts but also about understanding how this knowledge is obtained, evaluated, and applied in everyday life (Palines and Cruz, 2021). In the context of andragogy, where adult learners are considered to have developed critical thinking skills, scientific literacy becomes an important tool to help them critically evaluate information, make evidence-based decisions, and contribute to in-depth and informative scientific discussions.

The integration of an ethnoscience learning approach and scientific literacy skills has a significant impact on adult learning (Atmojo et al., 2019; Nurcahyani et al., 2021; Yuliana et al., 2021). For example, by integrating local wisdom in science learning, adult students can feel more involved and relevant to the material being taught. This can increase their motivation and interest in learning, which in turn can increase learning effectiveness (Yuliarti et al., 2023). Additionally, this approach also helps build a greater appreciation for cultural diversity in the classroom (Putra, 2021; Sotero et al., 2020). By strengthening students' cultural identities, the ethnoscience approach creates an inclusive learning environment and supports students' holistic growth. This is in accordance with the principles of andragogy, where the experience and background of adult learners are considered important in the learning process.

However, the challenge faced is how to integrate an ethnoscience learning approach and scientific literacy skills into an effective and comprehensive learning design. Collaborative efforts are needed between educators, researchers, and policymakers to develop learning strategies that suit the needs and characteristics of adult learners. In addition, improving training and education for educators in terms of implementing this approach is also very important. By strengthening the integration between ethnoscience learning approaches and scientific literacy skills in adult education, we can create learning environments that are supportive, inclusive, and relevant for all students (Dewi et al., 2019; Özburak, 2021; Sari et al., 2023). This will not only increase their understanding of science but also help them develop the skills and attitudes necessary to participate actively in a society increasingly dependent on science and technology.

In line with andragogy theory, this learning model values and respects the independence of students. From an andragogy perspective, the core ideas of inquiry-based learning, ethnoscience approaches, and scientific literacy skills are effective tools for supporting independent, adult-centered learning. By promoting active exploration, valuing local knowledge, and enhancing critical thinking, these three concepts work together to create a learning environment that helps adult learners reach their full potential.

Although this research offers a promising framework for integrating ethnoscience learning approaches with scientific literacy skills, areas for improvement still need to be addressed. One is that this model has yet to be empirically tested or compared with other existing learning models. Therefore, further research will be needed to overcome these limitations. Further research will be conducted by implementing this model in real-world settings. By conducting implementation trials, we can measure the effectiveness and advantages of this model more directly. Additionally, comparisons with existing learning models will be conducted to assess the effectiveness of this model in enhancing scientific literacy and student autonomy.

This further research can give us a deeper understanding of this model's potential and limitations. That will help develop this framework further and provide more solid guidance for educational practitioners in implementing suitable approaches to enhance scientific literacy among adult learners. Thus, the success and advantages of this approach can be empirically proven and can significantly contribute to the development of adult education.

4. Conclusion

From the description that has been presented, it can be concluded that the inquiry learning model has a very important role in stimulating curiosity, developing critical thinking skills, and promoting student independence in learning. Its basic philosophy, which emphasizes that learning is an endless process of exploration, provides a strong foundation for this approach. Its key characteristics, such as active engagement, leadership inquiry, critical engagement, collaboration, independence, and engagement with the real world, all contribute to a deep and meaningful learning experience for students.

However, to maximize the potential of inquiry learning, it is important to integrate other concepts and practices, such as ethnoscience learning approaches and scientific literacy skills. An ethnoscience approach enables recognition and respect for students' local and cultural knowledge, while scientific literacy provides a strong foundation for evidence-based and critical learning. By combining these three approaches, we can create a holistic learning environment and support overall student growth.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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