Jurnal Kependidikan:
Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran
https://e-journal.undikma.ac.id/index.php/jurnalkependidikan/index

Vol. 12, No. 3 : September 2026
E-ISSN: 2442-7667
pp. 1356-1367
Email: jklppm@undikma.ac.id

From Curriculum Integration to Classroom Practice: Assessing Primary School Teachers' Competence and Challenges in Contextual IPAS Learning

Brianne E.J. Komedien*, Deane Umboh, Jeane Kalengkongan
Universitas Negeri Manado, Indonesia.
*Corresponding Author. Email: brianne.komedien@unima.ac.id

Abstract: This study aims to assess primary school teachers' competencies in managing contextual IPAS (Integrated Science and Social Studies) learning and to identify the major challenges affecting its implementation in Tomohon City, Indonesia. A mixed-methods approach was employed, combining quantitative data from a structured questionnaire with qualitative data from classroom observations and semi-structured interviews. The participants comprised 40 primary school teachers from ten public schools selected through purposive sampling. The questionnaire consisted of 15 Likert-scale items covering three competency dimensions: science laboratory management, environment-based learning media management, and science content contextualization. Quantitative data were analyzed using descriptive statistics, while qualitative data were analyzed thematically. The results showed that only 45% of the teachers demonstrated good to excellent competence in managing contextual science learning, whereas 55% demonstrated moderate to low competence. The overall mean competency score was 58%, indicating a moderate level of competence. Among the three dimensions, science laboratory management received the lowest score (52.4%), followed by environment-based learning media management (58.7%) and science content contextualization (63.1%). Teachers reported persistent challenges in organizing practical science activities, developing contextual learning media, and integrating local environmental resources into inquiry-based instruction. This diagnostic profile addresses a gap in the literature by providing a detailed account of teachers' competencies in managing contextual science learning across three integrated dimensions. The findings provide an evidence-based foundation for curriculum developers and policymakers in Indonesia and other developing countries to design targeted professional development programs and support strategies. Such initiatives may strengthen contextual science education reform and support the effective implementation of the Merdeka Curriculum in primary schools.

Article History
Received: 22-06-2026
Revised: 25-07-2026
Accepted: 31-08-2026
Published: 20-09-2026

Key Words:
Contextual IPAS Learning; Teacher Competence; Curriculum Implementation; Primary Science Education; Teacher Challenges.

How to Cite: Komedien, B. E. J., Deane Umboh, & Jeane Kalengkongan. (2026). From Curriculum Integration to Classroom Practice: Assessing Primary School Teachers' Competence and Challenges in Contextual IPAS Learning. *Jurnal Kependidikan : Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran, Dan Pembelajaran*, *12*(3), 1356-1367. https://doi.org/10.33394/jk.v12i3.22011

https://doi.org/10.33394/jk.v12i3.22011

Introduction

Science education has become a global priority in preparing students to develop scientific literacy, critical thinking, and problem-solving skills needed to address increasingly complex environmental and societal challenges. International educational frameworks emphasize that science learning should move beyond the transmission of factual knowledge toward inquiry-based, contextual, and experience-oriented learning that enables students to investigate authentic phenomena and construct scientific understanding through direct engagement with their surroundings (OECD, 2023; UNESCO, 2021). This orientation is consistent with constructivist learning theory, which views scientific knowledge as actively constructed through learners' interaction with phenomena, prior experiences, observation, inquiry, and reflection (Taber, 2014). It is also aligned with place-based education, which positions the local environment as an authentic context for learning rather than merely as an illustration of scientific concepts (Sobel, 2020). Accordingly, effective primary science education requires teachers to create learning environments that connect scientific concepts with students' everyday experiences and local environmental contexts and provide opportunities for observation, investigation, experimentation, discussion, and reflection.

Managing contextual science learning requires teachers to integrate several instructional competencies rather than merely apply a particular teaching model. In this study, contextual science learning management is conceptualized through three interrelated dimensions: (1) science laboratory management, (2) environmental-based learning media management, and (3) science content contextualization. Laboratory management refers to teachers' ability to organize and conduct practical science activities, utilize available equipment, and support safe and meaningful investigations. Environmental-based learning media management concerns teachers' ability to identify, develop, select, and utilize concrete materials and resources available in the surrounding environment as learning media. Science content contextualization refers to teachers' ability to connect scientific concepts with students' everyday experiences, local phenomena, and authentic environmental contexts. These dimensions are important because hands-on and inquiry-oriented learning can provide opportunities for students to develop conceptual understanding and scientific reasoning, while place-based and environment-based learning can strengthen environmental awareness and engagement (Akuma & Callaghan, 2021; Sobel, 2020; Ardoin et al., 2023). Thus, teachers' competence in integrating practical activities, environmental resources, and contextual content constitutes an important condition for meaningful primary science learning.

In Indonesia, the demand for contextual and inquiry-oriented learning is reflected in the implementation of the Merdeka Curriculum, which introduces Integrated Natural and Social Sciences (Ilmu Pengetahuan Alam dan Sosial—IPAS) as an interdisciplinary learning area at the primary school level. IPAS encourages students to investigate relationships among humans, nature, technology, and society through meaningful learning experiences and therefore requires teachers to utilize local environmental resources, practical investigations, and contextual problem-solving (Kemendikbudristek, 2022). Although previous research has demonstrated the potential of inquiry-based, contextual, and place-based approaches to improve students' science learning, much of the existing literature has focused on student learning outcomes or the effectiveness of specific instructional models (Akuma & Callaghan, 2021; Ardoin et al., 2023). Comparatively less attention has been given to teachers' competencies as an integrated determinant of contextual science learning implementation. Existing studies also tend to examine laboratory activities, instructional media, contextual learning, or inquiry-based teaching separately. Consequently, empirical evidence remains limited regarding teachers' capacity to simultaneously manage practical science activities, environmental-based learning media, and science content contextualization within the implementation of IPAS under the Merdeka Curriculum. This gap highlights the need for a systematic diagnostic assessment of teachers' competencies across these interconnected dimensions.

This issue is particularly relevant in Tomohon City, North Sulawesi, an ecologically rich setting characterized by volcanic landscapes, biodiversity, agricultural systems, and diverse ecological phenomena. These environmental characteristics provide authentic opportunities for primary students to investigate scientific phenomena related to ecosystems, environmental change, natural resources, agriculture, weather, and human–environment interactions. However, the availability of rich environmental resources does not necessarily translate into effective contextual science learning because teachers need the competence to

Jurnal Kependidikan:
Jurnal Hasil Penelitian dan Kajian Kepustakaan
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https://e-journal.undikma.ac.id/index.php/jurnalkependidikan/index
Vol. 12, No. 3 : September 2026
E-ISSN: 2442-7667
pp. 1356-1367
Email: jklppm@undikma.ac.id

transform local phenomena into structured inquiry and learning experiences. Preliminary observations in ten public primary schools involving 40 teachers revealed a discrepancy between this environmental potential and classroom practice: only 45% of teachers demonstrated good competence in managing contextual IPAS learning, while many teachers experienced difficulties in organizing practical science activities, utilizing simple laboratory facilities, developing concrete instructional media, and integrating local environmental phenomena into classroom learning. This discrepancy indicates the need to systematically examine teachers' competencies and the challenges that influence their ability to transform Tomohon's environmental potential into meaningful contextual science learning.

Accordingly, this study aims to assess primary school teachers' competencies in managing contextual IPAS learning and identify the major challenges influencing its implementation in Tomohon City, Indonesia. Specifically, the study examines teachers' competencies in science laboratory management, environmental-based learning media management, and science content contextualization, while also identifying the challenges teachers encounter in implementing contextual IPAS learning. The novelty of this study lies in the application of a three-dimensional diagnostic framework that examines these competencies as an integrated construct rather than as isolated aspects of science instruction. By linking curriculum expectations with teachers' actual classroom competencies, the study provides an empirical profile of the extent to which contextual IPAS learning can be translated from curriculum policy into classroom practice. The findings are expected to provide an evidence-based foundation for curriculum developers and policymakers in Indonesia and other developing countries to design targeted professional development programs and instructional support strategies for strengthening contextual science education and supporting effective curriculum implementation.

Research Method

This study employed a mixed-methods approach to assess primary school teachers' competencies in managing contextual Integrated Natural and Social Sciences (IPAS) learning and to identify the major challenges influencing its implementation. The quantitative component was used to measure and describe teachers' competency levels across three dimensions of contextual IPAS learning management: science laboratory management, environmental-based learning media management, and science content contextualization. The qualitative component complemented the quantitative findings by providing contextual information on teachers' classroom practices and the challenges they encountered in implementing contextual IPAS learning, based on classroom observations and semi-structured interviews. The integration of quantitative and qualitative evidence enabled the study to develop a more comprehensive diagnostic profile of teachers' competencies and to identify specific areas requiring improvement in the implementation of contextual IPAS learning.

Figure 1 illustrates the overall research procedure adopted in this diagnostic study. The study began with a quantitative assessment using a structured questionnaire to identify teachers' competency profiles. The quantitative findings subsequently informed classroom observations and semi-structured interviews aimed at explaining the identified competency patterns and challenges. Finally, both quantitative and qualitative findings were integrated to provide a comprehensive diagnostic understanding of teachers' competencies in managing contextual IPAS learning.

Jurnal Kependidikan:
Jurnal Hasil Penelitian dan Kajian Kepustakaan
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Vol. 12, No. 3 : September 2026
E-ISSN: 2442-7667
pp. 1356-1367
Email: jklppm@undikma.ac.id

Diagnostic Descriptive Study

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Literature Review &
Instrument Development

↓

Questionnaire Survey
(40 Teachers)

↓

Classroom Observation

↓

Semi-structured Interviews

↓

Data Integration
(Descriptive & Thematic Analysis)

↓

Diagnostic Profile of Teachers'
Contextual IPAS Learning Competencies

Figure 1. Research Procedure

This sequential procedure enabled the quantitative findings to be interpreted more comprehensively through qualitative evidence obtained from classroom observations and teacher interviews. The participants consisted of 40 primary school teachers teaching Integrated Natural and Social Sciences (IPAS) in Grades 4–6 from ten public primary schools in Tomohon City, North Sulawesi, Indonesia. Participants were selected using purposive sampling based on three criteria: (1) actively teaching IPAS under the Merdeka Curriculum, (2) having at least one year of teaching experience in upper primary grades, and (3) being willing to participate in classroom observations and interviews. The participating schools were purposively selected because they had implemented the Merdeka Curriculum and offered Integrated Natural and Social Sciences (IPAS) in upper primary grades. Teachers were selected based on their direct involvement in teaching IPAS, ensuring that participants possessed relevant instructional experience for the objectives of this diagnostic study. Tomohon was selected because of its rich environmental characteristics, including volcanic landscapes, agricultural ecosystems, biodiversity, and local environmental phenomena—that offer authentic opportunities for contextual science learning in primary education. The demographic characteristics of participants are presented in Table 1.

Table 1. Characteristics of Participants (n = 40)

Characteristics	**n**	**%**
Male	10	25
Female	30	75
Teaching experience <5 years	12	30
Teaching experience 5–10 years	18	45
Teaching experience >10 years	10	25
Bachelor in Science Education	25	62.5

Jurnal Kependidikan:
Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran
https://e-journal.undikma.ac.id/index.php/jurnalkependidikan/index
Vol. 12, No. 3 : September 2026
E-ISSN: 2442-7667
pp. 1356-1367
Email: jklppm@undikma.ac.id

Bachelor in Primary Education	10	25
Master in Science Education	5	12.5

Based on a synthesis of the literature, teachers' competencies in managing contextual IPAS learning were operationalized into three interrelated dimensions representing essential aspects of contextual science learning management in primary education. Data were collected using a structured questionnaire, classroom observation sheets, and semi-structured interview guidelines. The questionnaire consisted of 15 Likert-scale items (1 = very low competence to 5 = very high competence) designed based on complementary theoretical perspectives, including contextual science learning (UNESCO, 2021), the OECD Science Literacy Framework (OECD, 2023), science learning management (Darling-Hammond et al., 2020), inquiry-based practical science learning (Akuma & Callaghan, 2021), and place-based education (Sobel, 2020). The three dimensions comprised science laboratory management, environmental-based learning media management, and science content contextualization. Classroom observation sheets were used to document teachers' implementation of practical activities, utilization of learning media, and integration of local environmental contexts during science instruction. Semi-structured interview guidelines were employed to explore teachers' experiences, perceived challenges, and professional development needs related to contextual IPAS learning. To ensure that the competency assessment comprehensively represented the construct of contextual IPAS learning management, the questionnaire was developed based on a synthesis of relevant theoretical perspectives. Three competency dimensions were operationalized into fifteen indicators, as presented in Table 2.

Table 2. Blueprint of the Teacher Competency Questionnaire

Dimension	Indicators	Item Numbers	Number of Items
Science Laboratory Management	Planning simple practical activities; organizing science investigations; utilizing laboratory equipment and materials; facilitating practical activities; assessing students' practical work	1–5	5
Environmental-Based Learning Media Management	Developing environmental learning media; utilizing local materials; adapting media to students' characteristics; integrating concrete learning resources; encouraging environmental observation	6–10	5
Science Content Contextualization	Relating science concepts to daily life; integrating local environmental phenomena; designing contextual science problems; facilitating inquiry discussions; promoting environmental responsibility	11–15	5

As shown in Table 2, the three dimensions collectively represent complementary aspects of contextual science learning management. Science laboratory management focuses on teachers' ability to facilitate practical investigations, environmental-based learning media management emphasizes the utilization of locally available learning resources, whereas science content contextualization reflects teachers' competencies in connecting scientific concepts with authentic environmental contexts.

Classroom observation sheets were used to document teachers' implementation of practical activities, utilization of learning media, and integration of local environmental contexts during science instruction. Semi-structured interview guidelines were employed to explore teachers' experiences, perceived challenges, and professional development needs related to contextual IPAS learning.

Jurnal Kependidikan:
Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran
https://e-journal.undikma.ac.id/index.php/jurnalkependidikan/index

Vol. 12, No. 3 : September 2026
E-ISSN: 2442-7667
pp. 1356-1367
Email: jklppm@undikma.ac.id

Content validity was established through expert review involving two science education experts and one experienced primary school teacher. Content validity was assessed using Aiken's V coefficient, with the item-level values reported in the results section. The internal consistency of the instrument was assessed using Cronbach's alpha separately for each of the three competency dimensions based on responses from the 40 participating teachers. The coefficients were 0.727 for science laboratory management (Items 1–5), 0.623 for environmental-based learning media management (Items 6–10), and 0.492 for science content contextualization (Items 11–15). Because the three dimensions represent conceptually distinct aspects of contextual IPAS learning management, reliability was examined separately for each subscale.

Data collection was conducted over a two-month period (April-May 2026) after obtaining approval from the local education authority and participating schools. Prior to data collection, all participants received information regarding the study objectives and voluntarily provided informed consent.

The data collection process consisted of three consecutive stages. First, teachers completed the structured questionnaire anonymously to obtain quantitative data regarding their competencies in managing contextual IPAS learning. Second, structured classroom observations were conducted to examine the implementation of practical science activities, environmental-based learning media, and contextual instructional practices. Finally, semi-structured interviews were conducted with selected participants to obtain more in-depth information regarding factors influencing teachers' competencies and the challenges encountered during classroom implementation.

Quantitative data were analyzed using frequencies, percentages, and mean scores. The final competency percentage was calculated as ($P=\frac{X}{Xmax}100\%$), where (X) is the observed score and (Xmax) is the maximum possible score. Competency levels were classified as Excellent (≥81%), Good (61–80%), Moderate (41–60%), and Low (≤40%). Qualitative data from classroom observations and semi-structured interviews were analyzed thematically following Braun and Clarke (2006) and used to complement the quantitative findings.

Results and Discussion

Competency Profile of Teachers

The competency assessment of 40 primary school teachers from ten public primary schools in Tomohon City revealed a moderate-to-good profile in managing contextual Integrated Natural and Social Sciences (IPAS) learning. Based on the 15-item instrument and the scoring procedure described above, the overall mean competency score was 61.67%. Using the predetermined competency categories, 21 teachers (52.5%) were classified as having good competency, while 19 teachers (47.5%) were classified as having moderate competency. No teachers were categorized as excellent or low. The overall distribution and mean scores across the three competency dimensions are presented in Table 3.

Table 3. Teachers' Competency Profile in Managing Contextual IPAS Learning (n = 40)

Competency Profile	Number of Teachers	Percentage	Mean Score (%)	Category
Excellent (≥81%)	0	0	0	
Good (61-80%)	21	52.5		
Moderat (41-60%)	19	47.5		
Low	0	0		

Vol. 12, No. 3 : September 2026
E-ISSN: 2442-7667
pp. 1356-1367
Email: jklppm@undikma.ac.id

(<40%)				
Overall Competency	40	100%	61.67	Good
Science Laboratory Managemant	-	-	57.20	Moderate
Environmental-Based Learning Media Management	-	-	60.30	Moderate
Science Content Contextualization	-	-	67.50	Good

Overall, the findings indicate a gap between teachers' ability to conceptualize contextual science learning and their ability to operationalize it through practical activities and environmental resources. This pattern is important for the implementation of the Merdeka Curriculum because contextual IPAS learning requires the integration of content, resources, and inquiry-oriented activities rather than contextualization through explanation alone. The results therefore point to the need for targeted professional development focusing particularly on practical science management, development and use of environment-based learning media, and the integration of these resources into inquiry-oriented classroom practice.

Competency Across Learning Management Dimensions

The assessment revealed clear differences in teachers' competencies across the three dimensions of contextual IPAS learning management (Table 3). Science laboratory management recorded the lowest mean score (57.20%) and was classified as moderate, followed by environmental-based learning media management (60.30%), also classified as moderate. Science content contextualization obtained the highest mean score (67.50%) and was classified as good. This pattern indicates that teachers were relatively more capable of connecting science content with students' experiences than of managing practical activities and systematically utilizing environmental-based learning resources.

Classroom observations provided further support for these findings. Practical science activities were implemented less frequently than classroom discussions and teacher explanations. Teachers with relatively higher competency scores more frequently engaged students in observation, questioning, and simple investigations using concrete materials available in and around the school environment. In these classrooms, students had opportunities to observe plants, discuss environmental phenomena, and relate scientific concepts to familiar situations. In contrast, teachers with moderate competency levels tended to rely more heavily on teacher explanations, textbook-based activities, and demonstrations, while opportunities for direct investigation and inquiry-oriented exploration were limited.

Interview findings identified several challenges that may constrain teachers' implementation of contextual IPAS learning. These included limited laboratory facilities and practical equipment, restricted opportunities for professional development, insufficient preparation time, and limited confidence in facilitating practical investigations. These challenges were particularly relevant to the lower performance observed in laboratory management and the use of environmental-based learning media.

The relatively higher score in science content contextualization suggests that teachers were generally more familiar with relating science concepts to students' everyday experiences. However, the observation findings indicate that contextualization was not always accompanied by hands-on investigation or systematic use of local environmental resources. In other words, teachers could explain the relevance of science concepts to students' lives, but translating that contextual orientation into authentic inquiry-based classroom activities remained inconsistent.

Overall, the findings suggest a gap between teachers' ability to contextualize science content conceptually and their ability to operationalize contextual learning through practical activities and environmental-based resources. This pattern highlights the need for targeted professional development that strengthens teachers' practical science management, development and use of environment-based learning media, and integration of these resources into inquiry-oriented IPAS instruction.

Challenges Reported by Teachers

Thematic analysis of classroom observations and semi-structured interviews identified four major challenges affecting teachers' competencies in managing contextual IPAS learning. First, limited laboratory facilities and practical equipment emerged as the most frequently reported challenge. Many teachers explained that the absence of adequate science equipment constrained their ability to organize hands-on investigations. Consequently, science learning was more commonly conducted through teacher explanations and textbook-based activities than through practical exploration. *"We rarely conduct science experiments because the available equipment is very limited. Most of the time, we explain the concepts using pictures or textbooks."* (Teacher 7)

Second, limited opportunities for professional development reduced teachers' readiness to implement contextual and inquiry-oriented science learning. Several participants reported that professional development activities primarily emphasized curriculum administration rather than practical strategies for organizing investigations, developing contextual learning media, or utilizing local environmental resources. *"Most training sessions focus on understanding curriculum documents, but we seldom receive practical guidance on conducting contextual science learning in our classrooms."* (Teacher 15)

Third, administrative responsibilities were perceived as reducing the time available for preparing practical science activities and contextual instructional media. Teachers acknowledged that designing inquiry-based lessons required additional preparation that was often difficult to accommodate alongside routine administrative duties. *"Preparing experiments and contextual learning materials takes time, while administrative work often becomes our priority."* (Teacher 22)

Fourth, limited confidence in facilitating inquiry-based investigations influenced teachers' instructional decisions. Several participants admitted that they were hesitant to organize practical investigations because they were uncertain about managing student activities or responding to unexpected situations during experiments. *"I sometimes worry that the investigation will not go as planned, so I prefer explaining the concepts directly rather than conducting experiments."* (Teacher 31)

Taken together, the qualitative findings indicate that teachers' challenges extend beyond individual pedagogical competence. Resource limitations, insufficient practical professional development, workload, and confidence in facilitating inquiry collectively constrain the translation of contextual IPAS principles into classroom practice. These findings are consistent with the quantitative pattern, particularly the relatively lower competency observed in laboratory management and environmental-based learning media management. At the same time, the comparatively higher competency in science content contextualization suggests that teachers may already possess a basic capacity to relate science concepts to students' experiences, but require greater support to translate this understanding into practical, environment-based, and inquiry-oriented learning activities.

Vol. 12, No. 3 : September 2026
E-ISSN: 2442-7667
pp. 1356-1367
Email: jklppm@undikma.ac.id

Discussion

Teachers' Competencies in Contextual Science Learning Management

The observed pattern suggests that teachers are more comfortable connecting science concepts to familiar experiences than organizing practical and inquiry-oriented learning. From a constructivist perspective, learning begins by connecting new knowledge with learners' prior experiences and meaningful contexts (Taber, 2014). Such contextualization can be facilitated through questioning, discussion, and everyday examples without requiring extensive changes in classroom organization (Furberg & Silseth, 2022; Silseth & Erstad, 2022). In contrast, inquiry-oriented practical learning requires teachers to simultaneously manage content, materials, student interactions, time, safety, and evidence-based reasoning. These demands may explain teachers' greater tendency toward verbal or narrative contextualization and their hesitation in conducting hands-on inquiry (Akuma & Gaigher, 2021; Photo, 2025).

This distinction is consistent with the broader understanding of effective science learning management as an integrated process involving pedagogical planning, instructional organization, learning resources, classroom interaction, and assessment (Darling-Hammond et al., 2020). Teachers are therefore not merely curriculum implementers but active agents who translate curriculum principles into meaningful classroom practice. Fitzgerald et al. (2021) similarly emphasize the importance of teachers' instructional competence and professional capacity in translating curriculum expectations into effective teaching practices. When teachers have limited practical experience, instructional confidence, or preparation time, direct explanation may be perceived as more manageable and predictable than open-ended investigation (Akuma & Gaigher, 2021; Markwick & Reiss, 2024). OECD (2023) and UNESCO (2021) further emphasize that meaningful science education requires teachers to facilitate inquiry, connect learning with authentic contexts, and engage students in investigating real-world phenomena.

From Local Environmental Potential to Classroom Practice

Tomohon provides a particularly relevant setting for contextual science learning because its volcanic landscape, biodiversity, agricultural environments, and geothermal phenomena offer authentic objects and processes for scientific investigation. However, place-based education emphasizes that local environments become meaningful learning resources only when teachers intentionally transform them into structured learning experiences (Sobel, 2020). Thus, the presence of rich environmental resources does not automatically ensure their pedagogical use.

The qualitative findings suggest a resource-to-pedagogy gap: teachers recognize local environmental phenomena as relevant examples but do not consistently transform them into learning media or inquiry activities. Such transformation requires teachers to select appropriate phenomena, connect them with curriculum objectives, prepare accessible materials, formulate investigation questions, and guide students in observing and interpreting evidence. This is consistent with the view that effective science learning management depends on teachers' capacity to select and organize learning resources in ways that support meaningful inquiry (Darling-Hammond et al., 2020). Place-based approaches likewise emphasize that local environmental resources become educationally meaningful when they are intentionally integrated into authentic inquiry and problem-solving activities (Vander Ark et al., 2020; Ayotte-Beaudet et al., 2023).

The situation in Tomohon therefore suggests that the central challenge is not simply the availability of environmental resources but teachers' capacity to transform those resources into pedagogically purposeful learning experiences (Yemini et al., 2023).

Vol. 12, No. 3 : September 2026
E-ISSN: 2442-7667
pp. 1356-1367
Email: jklppm@undikma.ac.id

Strengthening this capacity is particularly important in implementing IPAS because contextual and place-based learning requires students to engage with relationships among nature, society, and everyday life through authentic learning experiences (Yemini et al., 2023; Ge et al., 2026). Professional support should consequently provide teachers with practical models for transforming volcanic, agricultural, biodiversity, and other local phenomena into age-appropriate inquiry activities (Akuma & Koenen, 2025; Photo, 2025).

Implications for Professional Learning

The findings imply that professional development should move beyond general curriculum orientation toward sustained pedagogical support. Teachers need opportunities to collaboratively design simple investigations, develop low-cost environment-based learning media, implement lessons, and reflect on classroom practice (Benedict et al., 2023; Yang et al., 2022). Such continuous professional learning is consistent with the role of teachers as active developers of instructional practice rather than passive recipients of curriculum reform (Fitzgerald et al., 2021).

School–university partnerships and Teacher Professional Learning Communities, including Kelompok Kerja Guru (KKG), can provide sustained opportunities for collaborative lesson design, classroom mentoring, reflection, and collaborative inquiry (Yang et al., 2022; Ma & Green, 2023; Haavind, 2024). Such professional learning structures can strengthen teachers' capacity to connect professional learning with classroom practice through sustained collaboration and reflection (Sarmiento-Márquez et al., 2023; Wong et al., 2024). In Tomohon, these activities should be explicitly connected to local ecological characteristics. The development of Place-Based Micro-Science Kits using safe and locally available volcanic, agricultural, and biodiversity-related materials could help teachers translate local environmental potential into practical and inquiry-oriented IPAS learning. This approach directly responds to the pedagogical and resource-related challenges identified in the study while strengthening the connection between curriculum expectations and classroom practice.

Conclusion

This study concludes that teachers' competencies in managing contextual IPAS learning remain insufficient to fully support the implementation of inquiry-oriented and context-based science education envisioned in the Merdeka Curriculum. Although teachers demonstrated moderate competencies overall, the findings indicate that effective contextual science learning depends on the integration of science laboratory management, environmental-based learning media, and science content contextualization as complementary instructional management components rather than as separate teaching practices.

From a theoretical perspective, this study extends the discourse on contextual science learning by positioning teachers' competencies in managing contextual IPAS learning as an integrated instructional management construct. The findings demonstrate that successful contextual science learning is influenced not only by curriculum design or environmental availability but also by teachers' capacities to transform local resources into authentic inquiry-based learning experiences.

Practically, the findings suggest that strengthening contextual IPAS learning requires systematic professional development focusing on laboratory management, contextual instructional design, and the pedagogical utilization of local environmental resources. Such efforts are expected to support more meaningful science learning while improving the implementation of the Merdeka Curriculum in primary schools.

Recommendation

Based on the findings, schools and educational authorities should prioritize sustainable professional development programs that strengthen teachers' competencies in managing contextual IPAS learning. Rather than relying solely on one-off workshops, continuous professional learning should be facilitated through Lesson Study, Teacher Working Groups (Kelompok Kerja Guru/KKG), peer mentoring, and reflective teaching practices that enable teachers to collaboratively design, implement, and evaluate inquiry-based science lessons.

Considering the limited laboratory facilities identified in this study, school–university partnerships are recommended to support classroom mentoring, collaborative lesson design, and the development of mini-laboratory models utilizing low-cost and locally available materials. Such initiatives can assist teachers in implementing practical science activities despite limited school resources. At the policy level, continuous professional development programs should emphasize contextual instructional management, environmental-based learning media, and authentic assessment aligned with the Merdeka Curriculum. Future studies are encouraged to evaluate the effectiveness of these collaborative professional development models across broader educational contexts and examine their long-term impact on teachers' competencies, students' scientific literacy, and inquiry skills.

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