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Evaluating Science Curriculum Implementation through Students' Experiences and Opportunities to Learn in Frontier Schools in Southwest Papua, Indonesia

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Abstract
Equitable access to quality science education remains a critical global challenge, as standardized curricular reforms frequently encounter structural inequalities in geographically remote areas. Using a qualitative descriptive design informed by reflexive thematic analysis, this study examined how junior secondary students in a frontier (3T) setting in Southwest Papua Province, Indonesia, experienced discrepancies between national science curriculum expectations and their actual classroom learning opportunities, and how they responded to learning hurdles in science. Data were gathered from 10 students convenience sampled from 10 different schools through semi structured individual interviews organized around two domains, include students' experiences of curriculum–practice discrepancies, and learning hurdles and students' negotiation strategies. Regarding the first research question, students reported that topics prescribed by the national curriculum generally remained visible in classroom instruction, but that laboratory based, inquiry oriented, and locally contextualized learning opportunities were considerably reduced by resource limitations, out of field teaching, and geographic isolation. Regarding the second research question, the analysis indicated that learning hurdles had a double edged effect include constraints were associated with frustration and a view of science as abstract and memorization oriented, yet, when successfully negotiated through peer collaboration, digital resources, and local ecological knowledge, the same constraints could also support creativity and a more situated understanding of science. These findings suggest that standardized curriculum implementation does not by itself guarantee equitable opportunities to learn, pointing to a need for sensitive context, differentiated implementation support in frontier schools. As the study draws on a small, geographically bounded sample from Southwest Papua, the findings should be read as an in depth, contextually grounded account rather than a statistically generalizable one, future research could extend this work through classroom observation, teacher perspectives, and comparative frontier–urban designs.

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INTRODUCTION

The curriculum occupies a strategic position in science education as a primary instrument for shaping the quality of scientific literacy and the acquisition of scientific knowledge, which serve as essential resources for students to make evidence based decisions amid the complexity of socio-ecological issues (Assaf, 2023; Kirk et al., 2025). Globally, reforms in science education have shifted the paradigm from the passive acquisition of factual content toward the development of inquiry skills, critical thinking, problem solving, evidence based reasoning, as well as mechanistic reasoning and systems thinking (Lesnefsky et al., 2025). Modern science curricula at the junior secondary school level are designed to provide meaningful learning opportunities that enable students to conduct independent investigations, engage in experimentation, construct arguments based on empirical evidence, and connect scientific phenomena with real life contexts (Kirk et al., 2025; Lesnefsky et al., 2025). Accordingly, effective science learning recognizes that conceptual understanding is neither decontextualized nor static; rather, it develops continuously when students are given opportunities to engage in "doing science" through active participation in authentic scientific practices (Hodson, 2003; Lesnefsky et al., 2025; Millar, 2020). This pedagogical rationale underscores the premise that modern science curricula require meaningful learning opportunities in which students are provided with both the physical and intellectual space necessary to engage in authentic scientific practices.

Although national curriculum documents in many countries are developed according to idealistic and future oriented normative standards, the existence of such written standards does not automatically guarantee the realization of equitable learning experiences at the classroom level. This discrepancy has led science education research to adopt a tripartite analytical framework that conceptualizes curriculum across three distinct levels. The intended curriculum, the enacted curriculum, and the experienced curriculum (Chang et al., 2021; Clemmons et al., 2022; McCrory et al., 2021). The intended curriculum refers to the officially articulated vision, competency standards, and pedagogical blueprint formulated by educational policymakers at the macro level (Thompson & Usiskin, 2013). The enacted curriculum, by contrast, refers to the ways in which teachers interpret, adapt, and operationalize these plans through actual instructional activities in classrooms and laboratories (Clemmons et al., 2022; Rezvani & Farsimadan, 2025). Meanwhile, the experienced curriculum encompasses the accumulated experiences, meanings, and subjective perceptions directly constructed by students in response to the learning opportunities made available to them (Matthews & Mercer-Mapstone, 2018; Thompson & Usiskin, 2013). The gaps across these curricular dimensions demonstrate that the translation of educational policy is not a rigid or mechanical process but rather a complex form of implementation shaped by teachers' beliefs, school culture, and the availability of instructional support and resources (Doyle & Rosemartin, 2012; Remillard, 2005; Van den Akker, 2003). Studies of science curriculum implementation in rural and remote contexts further indicate that curriculum reforms may encounter substantial tensions when policy demands are misaligned with the pedagogical conditions and material realities of schools (Thijs & Van Den Akker, 2009).

Within Indonesia's national education system, successive curriculum reforms have been directed toward promoting student centered science learning, ranging from the emphasis on the scientific approach to the introduction of the *Kurikulum Merdeka* (Independent Curriculum). Policy analyses indicate that curriculum documents emphasize inquiry based approaches, problem based learning, and the exploration of contextual phenomena (Fitri et al., 2025; Irayanti, 2026). Normatively, the Indonesian curriculum requires graduates to develop higher order thinking skills and adequate scientific literacy to address problems encountered in society. Nevertheless, implementation at the school level reveals persistent alignment challenges, as teachers' understanding of national curricular regulations does not always translate into inclusive and authentic pedagogical practices in the classroom (OECD, 2018; Thijs & Van Den Akker, 2009). The decline in Indonesian students' science literacy scores in the international PISA assessment, from 396 in 2018 to 383 in 2022, provides an important empirical indication that national policy can remain largely confined to the level of formal documentation without being fully translated into students' actual learning experiences in classrooms (Harefa, 2024). Several studies examining the implementation of the scientific approach in Indonesia further confirm that teachers' understanding of national curricular requirements does not automatically correspond to the comprehensive implementation of all intended instructional components.

The dynamics of the gap between the written curriculum and its implementation in schools become particularly compelling when examined within Indonesia's highly heterogeneous geographical context, especially in frontier regions, including areas that are geographically remote, underserved, and disadvantaged (Fitri et al., 2025; Harefa, 2024). For clarity, this study uses the terms frontier, 3T (frontier, outermost, and least developed, from the Indonesian "terdepan, terluar, tertinggal"), remote, and border regions interchangeably to refer to Indonesia's geographically isolated and under resourced educational settings, consistent with usage in the literature cited throughout. Schools in these frontier regions operate within conditions of structural inequality and face persistent, systemic challenges in achieving educational development. These schools function under systematic disparities in educational resources, including the uneven availability and distribution of science teachers, the prevalence of out of field teaching, the absence of adequate laboratory facilities and representative practical equipment, limited electricity supply and internet connectivity, restricted access to high quality instructional materials, and limited opportunities for teachers to participate in sustained professional development (Ananda et al., 2025; Uno & Karim, 2025). These structural constraints are further compounded by geographical isolation, inadequate transportation infrastructure, differences between the formal language of instruction and local languages, and variations in family socioeconomic support, thereby creating boundary conditions that distinguish frontier schools substantially from their counterparts in urban centers (Reichert et al., 2022; Rosmana et al., 2022). Research on Indonesia's disadvantaged, remote, and frontier regions (3T areas) has likewise documented persistent structural challenges related to basic infrastructure, and the contextual relevance of the curriculum.

The structural constraints encountered by schools in frontier and border regions have particularly significant instructional consequences for science education, given the distinctive epistemic and pedagogical demands of the discipline compared with many other school subjects. Science learning requires physical interaction with materials and equipment, empirical observation, and experimental verification to support the development of conceptual abstractions. When the intended curriculum requires students to actively design experiments and test hypotheses, but schools lack even basic laboratory facilities, teachers in frontier regions may be compelled to make instructional compromises by simplifying learning content and activities to levels below the expectations established by the curriculum (Makori et al., 2025; Tran et al., 2023). Consequently, the enacted curriculum may shift from opportunities for independent inquiry toward textbook based theoretical instruction, one way lectures, or isolated teacher demonstrations conducted in front of the class. Over time, such instructional adaptations can constrain and distort students' experienced curriculum by reducing their opportunities to engage directly in scientific practices. Students who are expected to function as scientific investigators may instead become passive observers whose classroom participation is largely limited to taking notes and memorizing formulas (Amponsah & Mohammed, 2019; Ananda et al., 2025; Baidoo-Anu & Mensah, 2018). Studies of secondary schools in border and rural areas have similarly reported the continued dominance of teacher centered instructional practices, in which students' classroom activities are largely confined to listening and taking nonte, although a small number of teachers attempt to develop more active forms of learning despite limitations in practical resources. Such instructional adaptations, while often necessary under conditions of resource scarcity, substantially reduce students' opportunities to learn (OTL) science and may consequently constrain the development of their critical reasoning capacities from an early stage.

To establish a rigorous analytical framework, this study defines *learning hurdles* as a central operational concept. The absence of laboratory facilities, the scarcity of specialist science teachers, and inadequate internet connectivity constitute physical and structural barriers, however, *learning hurdles* focus more specifically on how these structural constraints are manifested, experienced, and perceived by students within the context of their everyday learning experiences (Chen et al., 2020; Tripp & Waight, 2024). The concept of *learning hurdles* encompasses students' difficulties in accessing hands on experimental experiences, limited opportunities for dialogic interaction with teachers, difficulties in obtaining supplementary learning resources, excessive reliance on textbook memorization, restricted opportunities to ask questions or engage in discussion, limited inquiry based activities, digital technology constraints, mismatches between science content and local ecological realities, difficulties arising from the formal language of instruction, and limited opportunities for collaboration with peers (Fasasi, 2017; Ibe & Nwosu, 2017; Sudarmin et al., 2018). By focusing the analysis on *learning hurdles*, this study conceptually moves beyond the identification of physical and structural barriers toward an examination of how such barriers constrain students' learning opportunities and ultimately become embedded in their lived experiences.

Within the literature on curriculum evaluation and educational reform, analyses of policy effectiveness have often been dominated by the perspectives of governments, educational administrators, school principals, and teachers. Such perspectives, however, may overlook the experiences of students, who are the primary recipients of and participants in curriculum implementation and who directly encounter the consequences of how the curriculum is enacted in classrooms (Moula & Guermat, 2026; Nguyen, 2026; Treacy et al., 2023). Students possess situated and experiential knowledge of the gap between what the curriculum promises and what the classroom actually provides (Beyessa, 2023; Nguyen, 2026). Therefore, student voice should not be treated merely as an additional instrument for qualitative data collection but rather as a fundamental epistemic position for evaluating the effectiveness of educational reform (Mitra, 2018). The success of curriculum implementation should not be assessed solely on the basis of teachers' administrative compliance with curricular regulations. Instead, it should also be evaluated from the perspective of students' actual experiences of the learning opportunities that are genuinely available to them in the classroom.

The cumulative learning hurdles experienced by students in frontier regions may have profound consequences for their affective and psychological orientations toward science as a discipline. Learning experiences that are limited, monotonous, and disconnected from local ecological realities may foster negative perceptions of science as excessively difficult, boring, and irrelevant to students' future lives and aspirations (Coffie et al., 2026). The systematic absence of opportunities for inquiry and exploration may gradually undermine students' self efficacy, weaken their sense of belonging within scientific communities, and constrain the development of their science identities (Archer et al., 2010; Coffie et al., 2026). Students in frontier and border regions may consequently perceive science and technology as exclusive domains reserved for urban students who have access to well equipped learning environments, thereby limiting their interest, learning motivation, and aspirations to pursue further education and STEM related careers (Chetcuti & Kioko, 2012; Lawer Egbenya & Kwesi Quayson, 2022). Accordingly, examining the relationship between *learning hurdles* and students' perceptions of science is crucial for understanding how educational inequalities may contribute to the continued marginalization of scientific talent in frontier and border regions.

Despite facing substantial disparities in educational facilities and infrastructure, students in frontier schools should not be viewed merely as passive victims lacking the capacity to influence or improve their learning conditions. Rather, they may demonstrate significant student agency in navigating and responding to the constraints embedded within their learning environments (Hodson, 2003; Niemi & Mclean, 2026). In the absence of formal laboratory facilities, for example, students may organize independent peer discussions, seek alternative learning resources by accessing the internet at locations where connectivity is available, actively seek assistance from teachers, contextualize scientific principles through local natural phenomena and Indigenous or local knowledge, and develop their own mechanisms of academic resilience (Pepin, 2021; Suwono et al., 2026). Shifting the analytical perspective from a deficit orientation toward an agentic perspective therefore creates conceptual space for examining how students actively position themselves as adaptive learning agents who negotiate constraints, mobilize available resources, and strive to sustain their educational progress despite the limitations of their learning environments.

Based on a critical synthesis of the literature discussed above, this study identifies a fundamental research gap across three conceptual dimensions include perspective, science specificity, and agency. First, most studies examining curriculum implementation in remote and underserved areas have focused predominantly on macro level policy evaluation, teacher perspectives, or school leadership, while comparatively few have positioned students' lived experiences as a primary epistemic standpoint for understanding and explaining curriculum gaps. Second, research on education in Indonesia's disadvantaged, remote, and frontier regions (3T areas) has generally addressed access limitations and infrastructure deficits as forms of general educational inequality, but has rarely examined in depth how these material constraints specifically reshape students' opportunities to learn science, particularly opportunities to engage in inquiry based and authentic scientific practices. Third, existing research has often portrayed students in frontier schools primarily as passive recipients of the consequences of educational inequality, with limited attention to how students actively negotiate, adapt to, and respond to learning hurdles in order to sustain their educational progress.

To address these three gaps in the literature, this study offers novelty through three principal dimensions of academic contribution. Empirically, it provides rich and contextually grounded qualitative evidence of science learning experiences articulated directly by students in frontier schools in Indonesia. Conceptually, the study integrates the intended–enacted–experienced curriculum framework, *learning hurdles*, the development of students' perceptions and identities toward science, and *student agency* within a coherent analytical framework. From a policy perspective, the study provides an empirical basis for educational policymakers to consider more sensitive context approaches to curriculum implementation and design that are responsive to the social, geographical, and material realities of Indonesia's disadvantaged, remote, and frontier regions.

Building on this rationale, the study seeks to address a fundamental question (1) How do students experience the discrepancies between national science curriculum requirements and their actual classroom learning opportunities in frontier educational settings? and (2) In what ways do learning hurdles in frontier schools influence students' perceptions of science, and how do students negotiate these challenges to sustain their educational progress?.

RESEARCH METHOD

This study employed a qualitative descriptive design informed by reflexive thematic analysis, following the approach developed by (Braun & Clarke, 2021, 2022), to explore how junior secondary school students experience the gap between national science curriculum standards and the realities of classroom learning in frontier regions, as well as how they negotiate learning hurdles to sustain their educational engagement. A qualitative approach was considered appropriate because the study sought to understand students' experiences, meaning-making processes, and strategies rather than to measure variables or estimate numerical relationships. In this respect, the research design was directly aligned with the two research questions, which addressed students' experiences of the curriculum–practice gap and the ways in which they negotiate learning hurdles. The design consequently positioned students as active interpreters of curriculum implementation whose accounts illuminate how curricular expectations are experienced and negotiated in everyday learning contexts, rather than treating them merely as recipients of curriculum implementation. The methodological reporting of the study was guided by the *Standards for Reporting Qualitative Research* (SRQR) and the *Consolidated Criteria for Reporting Qualitative Research* (COREQ), thereby ensuring systematic reporting of the research design, participants, data collection procedures, analytical processes, and strategies for establishing trustworthiness.

Within this design, the participants comprised 10 Grade 8 and Grade 9 students recruited from 10 different junior secondary schools across Southwest Papua Province, Indonesia. Participants were selected through convenience sampling according to four criteria. They were enrolled in Grade 8 or Grade 9, were currently engaged in science learning, had direct experience with the learning conditions examined in the study, and were willing to participate in an individual interview. Students were approached through school administration and teacher contact, and interviews were conducted in Indonesian language, with transcripts translated into English for analysis and reporting where necessary. Because access was mediated by school staff, convenience sampling carries a risk of selection bias, as students who were most accessible, communicative, or encouraged to participate by teachers may differ systematically from less visible or lower-achieving peers. This risk was partly mitigated by recruiting one participant from each of ten different schools rather than concentrating recruitment within a single site, though it cannot be fully ruled out and is acknowledged as a limitation of the design. The sample was not intended to achieve statistical representativeness. Rather, it was designed to provide sufficient depth and cross contextual variation for understanding students' experiences across different school settings. This sampling rationale is consistent with (Braun & Clarke, 2021) position that sample adequacy in reflexive thematic analysis should be considered in relation to the research purpose, the specificity of the participant group, the quality of the interview data, and the analytical approach, rather than being determined solely by the number of participants. The Southwest Papua context was selected because the implementation of a nationally standardized science curriculum occurs across schools that vary substantially in their access to learning resources, laboratory facilities, textbooks, internet connectivity, and opportunities for practical science activities. Accordingly, geographical context was treated as an analytically significant dimension of the study rather than merely as a descriptive feature of the research setting, allowing the analysis to consider how structural and geographical conditions shape students' opportunities to experience the curriculum in practice.

In accordance with this research design, particular attention was given to ethical procedures for research involving adolescent participants. Parental permission and student assent were obtained after participants and their parents or guardians had been provided with clear information concerning the objectives and procedures of the study, their right to decline to answer any question, and their right to withdraw from participation without academic consequences. To protect confidentiality, participants' identities were anonymized through the use of coded identifiers based on participant initials rather than their actual names. Institutional permission was obtained from the participating schools, while ethical approval was granted by the relevant Faculty Ethics Committee. These procedures were implemented not only to satisfy formal ethical requirements but also to create conditions in which students could discuss their learning experiences freely, particularly when describing limitations in school resources, classroom practices, or opportunities for science learning.

Data were subsequently collected through individual semi structured interviews using a researcher developed interview guide comprising 12 open ended questions organized around two substantive domains corresponding to the research questions. The first domain, consisting of six questions, explored students' experiences of the curriculum practice gap, including perceived differences in curricular content, classroom and laboratory conditions, school level responses, teachers' contextualization of science learning, and students' emotional responses to their learning experiences. The second domain, also comprising six questions, focused on learning hurdles and students' negotiation strategies, including changes in their perceptions of science, discrepancies between curricular content and local realities, strategies for overcoming learning difficulties, and recommendations for adapting science learning to local contexts. Before data collection, the interview guide was reviewed by four experts with expertise in science education, curriculum studies, and educational assessment. The expert review considered the relevance of the interview content, clarity of the questions, developmental appropriateness for adolescent participants, and neutrality of the language used. Given the interpretive nature of qualitative inquiry, methodological consistency was not assessed through statistical reliability coefficients. Instead, it was supported through the use of a standardized interview protocol, systematic documentation of any modifications to the interview procedure, ongoing researcher reflexivity, and maintenance of an analytical audit trail.

The data collection process proceeded through four interconnected stages, beginning with pre-fieldwork preparation, including ethical approval and validation of the interview guide, followed by participant recruitment and the completion of informed consent and assent procedures. Data collection took place over a period of June 2026. The third stage involved individual interviews lasting approximately 30 minutes, which were conducted in private settings to minimize potential influence from teachers and peers and to encourage participants to articulate their experiences openly. With participants' permission, the interviews were audio recorded to facilitate accurate verbatim transcription. Following transcription, the recordings and transcripts were checked for accuracy, personally identifying information was removed, and each transcript was assigned a participant code before entering the analytical process. This systematic preparation ensured that the interview data retained the participants' accounts while protecting their privacy throughout the research process. The data were then analyzed using the six phases of reflexive thematic analysis described by (Braun & Clarke, 2021). The first phase involved familiarization with the dataset through repeated reading of the interview transcripts and repeated listening to the audio recordings. The second phase involved systematic coding of data relating to curriculum–practice gaps, resource limitations, pedagogical adaptations, emotional responses, perceptions of science, and strategies for overcoming learning hurdles. In the third phase, related codes were examined and organized into candidate themes, after which the fourth phase involved reviewing and refining these themes against both the relevant data extracts and the dataset as a whole. The fifth phase focused on developing precise definitions and names for the final themes, while the sixth phase involved constructing the final analytical narrative by integrating thematic interpretations with illustrative quotations from participants. NVivo software was used to facilitate data organization and coding. The analytical process combined deductive sensitivity, in which the two research questions served as initial analytical domains, with an inductive orientation that allowed unexpected patterns, meanings, and interpretations to emerge from participants' accounts.

The trustworthiness of the study was addressed through the principles of credibility, transferability, dependability, and confirmability. Credibility was strengthened through several complementary procedures, including methodological triangulation involving comparison of students' accounts across the 10 participating schools, comparison across the two interview domains, peer examination of the coding process, member checking, and independent peer debriefing. Member checking involved returning summarized interpretations to participants to confirm that they reflected the intended meaning of their responses, while peer debriefing involved an independent qualitative researcher reviewing a subset of transcripts and coding decisions to challenge assumptions and surface alternative interpretations. In this study, agreement among researchers was not treated as a statistical indicator of coding reliability but rather as an opportunity to critically examine and challenge analytical assumptions and interpretations. Dependability was supported through a detailed audit trail documenting the research procedures, methodological modifications, coding decisions, and analytical development throughout the study. Confirmability was enhanced by maintaining a traceable link between the raw interview transcripts, analytical codes, developed themes, and the participant quotations used to substantiate the findings. Transferability, meanwhile, was supported through thick description of the participants, participating schools, and broader educational context including, where ethically permissible, variation in school location, grade level, and access to internet connectivity and laboratory facilities enabling readers to assess the relevance and potential applicability of the findings to other frontier or geographically comparable educational settings. These procedures were intended to ensure that the interpretations remained grounded in participants' accounts while acknowledging the interpretive role of the researcher in reflexive thematic analysis.

The research protocol received approval from the institutional ethics committee, and institutional permission was obtained from the relevant educational institutions and participating schools. All participating students and their parents or guardians received comprehensive information about the study and provided the required consent and assent before the interviews commenced. Because discussing limitations in school facilities, teaching practices, or learning opportunities could potentially cause discomfort or raise concerns about privacy, particular care was taken to frame the interview questions around students' experiences rather than evaluations or judgments of individual teachers or schools. Interviews were conducted privately, participant identities were removed from the research records, and coded identifiers were used throughout the data management and reporting processes. These safeguards were intended to minimize potential ethical risks while enabling students to provide candid accounts of how they experienced the relationship between national curriculum expectations and the realities of science learning in frontier educational contexts.

RESULT AND DISCUSSION

The thematic analysis of the student interview data generated five interrelated themes that illuminate how students in Indonesia's frontier educational settings experience the discrepancy between national science curriculum expectations and the learning opportunities available in their classrooms. The analysis focused on students' accounts of curriculum implementation, classroom and laboratory conditions, pedagogical practices, emotional responses to learning constraints, perceptions of science, and strategies for maintaining educational progress. The interview protocol was explicitly designed to examine the relationship between the "desired" curriculum represented by national standards and textbooks and the curriculum actually experienced by students in their classrooms, followed by questions concerning the effects of learning barriers and students' strategies for negotiating them. Five themes emerged from the data include (1) curriculum alignment accompanied by selective reduction of learning experiences; (2) infrastructural constraints and the transformation of laboratory based learning; (3) the importance and uneven implementation of local contextualization; (4) emotional and perceptual consequences of learning hurdles; and (5) student agency, peer support, and persistence as mechanisms for maintaining educational progress. Across these themes, the findings indicate that students did not primarily experience a complete divergence between the national curriculum and classroom instruction. Rather, they experienced a gap in the quality, depth, and experiential opportunities through which the curriculum was enacted.

The first theme concerns how students perceived the relationship between the national science curriculum and what was actually taught in their classrooms. Students generally recognized that teachers followed the broad content prescribed in national science textbooks. However, they also reported that the curriculum was frequently simplified, shortened, or selectively implemented because of limitations in time, equipment, and learning resources. One student explicitly stated: "The material remains the same, but the textbook is broader and more ideal, whereas what is taught is simplified and adjusted to the conditions of our school." This statement illustrates an important distinction between *curriculum content* and *curriculum enactment*. The national curriculum remained visible in classroom instruction, but its practical and inquiry oriented dimensions were reduced when local conditions made full implementation difficult.

A similar perception appeared in another student's account: "There is no different material from the national science textbook, but teachers usually add some material that they consider absent from the book." This suggests that teachers were not simply omitting curriculum content. They were also exercising professional adaptation by adding explanations or examples that they considered relevant to students' learning needs. Nevertheless, this flexibility coexisted with substantial omissions. One student explained: "It is not sufficient because practical activities and materials requiring special equipment, such as electricity or microscopes, are often skipped." Another student offered a personal estimate that the discrepancy between textbook expectations and classroom practice was around 30–40%. This is a subjective impression rather than a systematically measured figure explaining that practical activities were frequently shortened or omitted because of insufficient equipment, materials, or time.

Students further explained that activities involving direct experimentation, lengthy observation, or extended discussion were among the components most likely to be reduced. One participant identified "direct experiments or practical activities" as frequently omitted, while difficult topics, topics considered less likely to appear in examinations, and activities requiring considerable discussion or observation were also more likely to be shortened. The analytical interpretation is therefore that the curriculum–practice discrepancy was not primarily a matter of teachers teaching entirely different scientific content. Instead, the discrepancy emerged through selective reduction of the experiential dimensions of science learning. Students could encounter the same concepts specified in the curriculum but with fewer opportunities to observe, experiment, investigate, discuss, and apply those concepts.

The second theme concerns the material conditions in which science learning occurred. Students repeatedly contrasted the laboratories represented in textbooks or online learning resources with the facilities available at their schools. One student described the laboratory represented in textbooks as "bright, spacious, clean, and well organized," with complete equipment, while the school laboratory had very limited practical equipment, sometimes poor lighting, and crowded seating. The student concluded: "We only look at pictures or listen to the teacher's explanation, we rarely get to try things ourselves as shown in the textbook." Another student similarly explained that although a laboratory space was available, its equipment was incomplete and the laboratory was rarely used for practical activities.

These accounts indicate that infrastructure affected more than the physical comfort of students. It shaped the kinds of scientific experiences that students could access. Where the curriculum and textbooks presented science as an activity involving experimentation and direct observation, students sometimes encountered science predominantly through teacher explanations, textbook illustrations, or theoretical descriptions. In this sense, the infrastructural gap became a pedagogical gap.

However, students also described adaptive responses to these constraints. One student explained: "Our teachers often use videos from YouTube or use materials from the surrounding environment, for example, an experiment on water pressure using a used bottle instead of the laboratory equipment that should be used." Another student described how students were asked to collect leaves, soil, water, or used objects from their homes or school environment when laboratory materials were unavailable. When equipment was completely absent, practical work could be replaced with theoretical explanation or videos showing experiments. These findings suggest that material scarcity did not completely eliminate practical science. Instead, it produced pedagogical substitution and improvisation, whereby teachers attempted to preserve aspects of experimentation using locally available materials or digital representations. Nevertheless, students' accounts indicate that such alternatives did not always provide the same degree of direct engagement as conventional laboratory practice.

The third theme concerns the role of local context in helping students understand scientific concepts.

Students generally perceived contextualized teaching positively when teachers connected abstract concepts with familiar objects, environments, and everyday experiences. One student explained: “Our teachers often give examples from the surrounding environment, such as explaining photosynthesis using a mango tree in the school yard, so it is easier to imagine than simply reading a book.” Another student emphasized that conducting practical activities after receiving theoretical explanations helped them understand the material more effectively.

However, contextualization was not consistently experienced. A student from Yefman observed: “Sometimes the teacher does mention examples that are close to us, but very rarely discusses them in depth or takes us to observe them directly.” The finding suggests that local contextualization was recognized by students as an important pedagogical resource, but its implementation remained uneven. Consequently, students could simultaneously experience science as relevant and distant, depending on the extent to which teachers connected curriculum content with their immediate environment.

This issue became particularly evident when students discussed science topics involving places or phenomena that were absent from their everyday lives. One student stated: “For example, the material about snow there is no snow in our area, so it is difficult to imagine.” Another student explained that examples involving desert animals, seasonal forests, or advanced technological equipment were difficult to relate to life in Yefman. “I find it difficult to imagine them and feel that the material is not connected to my life. As a result, my enthusiasm for learning decreases.” Importantly, students did not necessarily reject unfamiliar scientific knowledge. Rather, their engagement appeared to depend on whether teachers provided an interpretive bridge between unfamiliar phenomena and familiar experiences. One student explained that interest increased when topics such as snow were connected to videos, images, climate, and Indonesian contexts, concluding that “the key is that teachers must be able to bridge the material with local examples.” Thus, geographical and cultural context emerged as an important mediator of students’ perceptions of scientific relevance.

The fourth theme captures the emotional and perceptual consequences of learning under constrained conditions. Students described feelings of sadness, frustration, being overwhelmed, and perceived disadvantage when curricular expectations were high but access to books, internet connectivity, laboratory equipment, and practical opportunities was limited. One student described the experience as “difficult and sad, because the learning targets are high while the facilities in Yefman are very limited.” The student nevertheless explained that they continued to listen carefully to teachers and share notes with peers. Another participant recalled initially feeling “frustrated and overwhelmed” because scientific concepts appeared easy in textbooks but became difficult when students were expected to conduct practical activities with limited resources.

These experiences sometimes influenced how students viewed science itself. One student explained that because science learning was often theoretical, they initially began to perceive science as “just memorization.” However, the student subsequently recognized that science remained important and that the main challenge was finding more creative ways to learn it. Another student described a similar transformation: “I used to think science was difficult and distant. Now I know that science is everywhere.” These accounts demonstrate that learning hurdles did not produce a single, uniform response. Constraints could reduce students’ motivation when science appeared disconnected from their everyday lives, but they could also encourage students to reconsider science as something observable in ordinary environments.

The data therefore reveal a dual effect of educational constraints. On one hand, limited resources could reinforce perceptions of inequality and make science appear inaccessible. On the other hand, successful adaptation could foster creativity and a more situated understanding of science. This duality is particularly important for understanding students’ experiences in frontier schools because the same material constraint could function simultaneously as a barrier and as a stimulus for alternative forms of learning.

The fifth theme concerns the strategies students developed to negotiate learning barriers. Rather than describing themselves solely as passive recipients of inadequate resources, students reported actively searching for alternative ways to understand unfinished or difficult material. Their strategies included watching YouTube videos, asking peers for explanations, borrowing classmates’ notes, rereading textbooks, searching for examples and practice questions, writing summaries, and consulting teachers outside regular instructional time. One student explained: "I often ask friends who understand better or borrow their notes, and I often watch learning videos on YouTube. I also frequently read the textbook so that I can understand." Another described rereading difficult sections, identifying confusing points, asking teachers during breaks, and connecting concepts with familiar elements of the surrounding environment.

These strategies demonstrate that students exercised agency by constructing additional learning opportunities beyond formal classroom instruction. Their agency was not exclusively individual. Peer collaboration emerged as an important mechanism for compensating for resource limitations. Students described sharing notes, asking classmates for explanations, and working together when they encountered difficult concepts. Teachers also remained an important source of support when students could not resolve difficulties independently.

The tenth interview question provided particularly strong evidence of persistence through resourceful experimentation. One student recalled learning about simple electrical circuits when no laboratory equipment was available. The students used "star fruit, a 1,000 rupiah coin, wire, and a small lamp," and after several attempts the lamp eventually became bright. The student explained: "What kept me going was curiosity and support from friends. We helped each other and laughed together when we failed. From that, I realized that failure is part of the scientific process." Another student described understanding plant reproduction by observing banana and mangrove plants near the home despite having only one textbook and limited equipment. "Finally, I understood the concept without buying anything." The student identified future aspirations, the desire to demonstrate competence despite limited resources, and the wish to help parents and peers as sources of persistence.

Students also explicitly identified structural inequalities between frontier and urban educational settings. The major challenges included limited laboratory equipment, insufficient supplementary books, unstable or slow internet access, limited tutoring opportunities, and fewer learning resources. One student observed that urban students had greater access to laboratories, internet, and additional tutoring, whereas students in their own area often had to rely heavily on teacher explanations. At the same time, the student identified a distinctive strength: "We have an advantage, we know the surrounding environment very well." This observation is significant because students did not construct their educational identity exclusively through a deficit perspective. Although they clearly recognized material inequalities, they also perceived familiarity with the natural environment as a potential educational resource.

Finally, students' responses to the twelfth question revealed their capacity to envision a more context responsive science curriculum. One student proposed replacing generic examples with "the sea, mangroves, *sasi*, and plants and animals typical of Papua," arguing that such examples would make science easier to understand and demonstrate its usefulness in everyday life. The same student recommended increasing direct observation in coastal and natural environments and simplifying topics that were particularly distant from local realities. Another student proposed replacing snow related examples with locally relevant phenomena such as sea winds and tides and using household materials for practical activities. These responses indicate that students were not merely negotiating an existing curriculum. They were articulating an alternative model of curriculum enactment based on local relevance, ecological familiarity, accessible materials, and direct observation.

Taken together, the findings indicate that students experienced the discrepancy between national science curriculum standards and classroom practice primarily as a narrowing of learning opportunities rather than a wholesale departure from curriculum content. The broad topics prescribed nationally generally remained present in classroom instruction, but opportunities to experiment, access information, discuss extensively, observe phenomena directly, and connect abstract concepts to everyday environments were considerably more constrained. These learning hurdles carried complex consequences for students' perceptions of science, at times producing frustration, feelings of disadvantage, and a view of science as primarily theoretical or based memorization, while also encouraging creativity, resourcefulness, collaboration, and recognition that scientific phenomena could be investigated using ordinary materials and local environments. Students' strategies including peer learning, independent reading, digital resources, consultation with teachers, and observation of local ecological phenomena reflected active forms of educational agency, reinforced by curiosity, peer support, and future aspirations.

The final pattern emerging from the thematic analysis is therefore a tension between standardization and contextual responsiveness. Students value access to the knowledge represented in the national curriculum, but they also express a clear need for that knowledge to be translated into forms that are meaningful and feasible within their geographical and material circumstances. Their recommendations to use Papua's coastal environments, mangroves, local plants and animals, *sasi*, sea winds, tides, household materials, and direct environmental observation indicate that contextual adaptation is not perceived as a lowering of academic expectations. Instead, students view contextualization as a means of making national science learning more understandable, engaging, and attainable. The findings consequently suggest that the central challenge in frontier science education is not simply whether students receive the national curriculum, but whether they are provided with equitable opportunities to experience science as inquiry, experimentation, contextual understanding, and meaningful participation. In this respect, students' narratives reveal both the structural limitations of frontier schooling and the considerable agency through which they negotiate those limitations to sustain their educational progress. It should be noted that these patterns were not uniform across all ten participants. Students varied in the intensity of the emotional responses they described, in the extent to which they had access to digital alternatives such as internet-based videos, and in how readily they identified locally relevant examples to compensate for unfamiliar curriculum content, these variations are treated here as part of the range of experience within frontier schooling rather than as evidence of a single, homogeneous student response.

Interpreting the Curriculum–Classroom Gap from Students' Perspectives

The findings of this study, addressing the first research question, indicate that the gap between national science curriculum standards and classroom practice in Indonesia's frontier regions is not experienced by students as a wholesale substitution of curriculum content. Students consistently recognized that the topics prescribed in national textbooks remained visible in their classrooms; what diverged was the depth, form, and experiential quality of the learning opportunities through which those topics were delivered. As one student summarized, "the material remains the same, but the textbook is broader and more ideal, whereas what is taught is simplified and adjusted to the conditions of our school," while another offered a personal estimate not a systematically measured figure that the discrepancy between textbook expectations and classroom practice was around 30–40 percent, attributing the gap primarily to the omission of practical activities requiring equipment such as electricity or microscopes rather than to any alteration of subject matter. These findings suggest that the curriculum–practice gap is not merely a matter of inadequate implementation but reflects a structural misalignment between nationally standardized expectations and the material and pedagogical conditions available in frontier schools. Students in this study appeared able to distinguish curriculum content from curriculum enactment, and tended to locate the source of the discrepancy not in their own capacity but in the conditions surrounding their schooling. This distinction resonates with international scholarship on curriculum fidelity and adaptation, which frames enacted curriculum as jointly constructed by teachers and students under local constraints rather than as a direct transmission of a centrally designed document (Tutal, 2026). In the Indonesian context specifically, (Farihen et al., 2026) describe a comparable pattern of epistemic fragmentation in frontier, outermost, and least-developed (3T) schools, in which curriculum enactment is governed more by administrative compliance than by contextual pedagogical competence. The present findings extend this argument from the standpoint of the teacher, which dominates prior literature, to the standpoint of the student, showing that the same structural condition is legible to and interpreted by the young people who live through it.

Learning Hurdles as Structural Constraints Rather Than Individual Deficits

The learning hurdles identified in this study cannot be reduced to deficiencies of individual student motivation or ability. Rather, they emerge from the interaction of material, pedagogical, and geographical conditions that constrain the range of classroom opportunities available. Material constraints were the most visible, students described school laboratories that, unlike the "bright, spacious, clean, and well organized" facilities depicted in textbooks, offered incomplete equipment and crowded seating, prompting one student to observe, "we only look at pictures or listen to the teacher's explanation, we rarely get to try things ourselves as shown in the textbook." Pedagogical constraints followed directly from this material scarcity, as instruction shifted toward lecture-based and representational modes whenever direct experimentation was not feasible. Geographical constraints compounded these conditions, schools situated in frontier locations such as Yefman face limited access to supplementary books, unstable internet connectivity, and reduced opportunities for external tutoring, echoing the broader pattern of educational access disparities documented in Indonesia's outer regions (Nugraha & Bajari, 2022) and the persistent infrastructural and connectivity gaps that characterize rural science instruction internationally (Khan et al., 2019; Kizilcec et al., 2021). Institutional constraints were evident in teachers' reliance on individual improvisation rather than systemic support, a pattern documented across resource-limited science classrooms in other national contexts (Botes & Blennis, 2025; Dhurumraj & Moola, 2023; Mabasa & Singh, 2020). This interpretive framework conceptualizes learning hurdles as emerging through a sequential interaction among national curriculum expectations, school-level conditions, classroom learning opportunities, and students' actual learning experiences. From this perspective, learning hurdles are understood not as evidence of deficiency among frontier students or their teachers, but as the outcome of interconnected structural and contextual conditions (Perry et al., 2024). This interpretation is consistent with the broader argument that students' opportunity to learn is shaped by multiple layers of institutional, pedagogical, and geographical conditions rather than by exposure to curricular content alone.

Consequences for Students' Perceptions of Science

Addressing the first component of the second research question, the findings show that limited opportunities for experimentation shaped how students understood the nature of science itself, not merely how much science content they retained. One student explained that because science instruction was so often theoretical, they initially began to perceive science as "just memorization." Limited opportunities for experimentation appeared to shape science not as an empirical and exploratory practice, but as a predominantly textual and procedural school subject, a shift that, while not directly measured in this study, may carry implications beyond immediate academic performance, as prior research suggests that science identity and a sense of belonging in science depend substantially on direct, hands on engagement rather than on passive content coverage (Godec et al., 2017; Zhai et al., 2024). Distance from students' everyday environments compounded this abstraction. One student noted that "the material about snow there is no snow in our area, so it is difficult to imagine," while another explained that unfamiliar examples involving desert animals or advanced technological equipment left them feeling that "the material is not connected to my life. As a result, my enthusiasm for learning decreases." Yet the data do not support a uniformly negative trajectory. Several students described a marked reorientation once science was reframed through familiar phenomena: "I used to think science was difficult and distant. Now I know that science is everywhere." This duality is consistent with international evidence that constrained access to real world, hands on STEM experience can depress rural students' engagement (Li et al., 2025), while also showing that the same constraint, once mediated by contextualization or improvisation, need not permanently foreclose scientific curiosity.

Students as Active Negotiators of Educational Constraints

Addressing the second component of the second research question, the findings show that frontier students did not respond to learning hurdles as passive recipients of an inadequate system. Instead, they actively constructed alternative learning pathways include watching instructional videos, consulting peers and teachers outside formal class time, borrowing and sharing notes, and searching for supplementary explanations. The most striking illustration of this agency was the construction of a working electrical circuit from "star fruit, a 1,000 rupiah coin, wire, and a small lamp," which one student described as sustained by "curiosity and support from friends," concluding that "failure is part of the scientific process." Another student described understanding plant reproduction by observing banana and mangrove plants near their home despite owning only one textbook, remarking, "finally, I understood the concept without buying anything." This pattern of Constraint, Adaptation, Agency and Educational Persistence positions frontier students as active negotiators of educational inequality rather than as its passive subjects, a reframing consistent with international literature on student agency, which characterizes agency as active negotiation with structural constraints rather than mere endurance of them (Inouye et al., 2023), and with evidence that peer tutoring and collaborative strategies are especially consequential for achievement in resource constrained science classrooms (Ala & Antonio, 2026). It also aligns with a broader body of research on funds of knowledge (Denton & Borrego, 2021; Moll, 2019), which documents how students and families draw on culturally and environmentally embedded resources to compensate for gaps in formal instructional provision.

Negotiating the Meaning of "Learning Science" in Frontier Contexts

The findings indicate that the central issue in frontier science education is not simply that students receive "less science" than their urban counterparts, but that they encounter a qualitatively different form of science learning shaped by the interaction between national curricular expectations and local educational realities. When teachers succeeded in linking abstract concepts to the immediate environment explaining photosynthesis, for instance, using "a mango tree in the school yard" students reported that comprehension improved markedly. Yet this contextualization remained uneven, a student from Yefman observed that "sometimes the teacher does mention examples that are close to us, but very rarely discusses them in depth or takes us to observe them directly." Students did not merely tolerate this tension, they actively proposed an alternative model of curriculum enactment grounded in ecological familiarity, recommending that generic examples be replaced with "the sea, mangroves, *sasi,* and plants and animals typical of Papua," and that snow-related material be substituted with locally relevant phenomena such as sea winds and tides. This finding extends a growing body of Indonesian ethnoscience scholarship documenting the pedagogical value of integrating indigenous and local ecological knowledge into science instruction (Kasi et al., 2021; Parmin & Taufiq, 2020; Suprapto et al., 2021), and parallels international place-based science education research demonstrating that local rural knowledge can be systematically integrated with national science standards without compromising academic rigor (Iturbe-Sarunic et al., 2025). Rather than a deficit to be remediated, students' ecological familiarity functioned as a distinct epistemic resource that could anchor, rather than replace, the national curriculum.

The Curriculum–Practice Gap as an Equity Issue

Raised to the level of educational equity, these findings raise a pointed question, what does it mean when the same national curriculum is implemented under radically different learning conditions? Students explicitly recognized this asymmetry, observing that peers in urban schools had access to functioning laboratories, stable internet, and supplementary tutoring, while their own learning depended heavily on teacher explanation and improvisation. Two students exposed to an identical national syllabus may therefore encounter fundamentally different opportunities to learn depending on the material and pedagogical conditions of their schools, meaning that curricular equality should be distinguished from equality of learning opportunities. This distinction is consistent with the opportunities and conditions to learn framework, which conceptualizes opportunity to learn as shaped not only by content exposure but by a layered set of structural and geographical conditions that are frequently allocated inequitably (Perry et al., 2024), and with evidence that infrastructural and connectivity disparities systematically disadvantage geographically isolated schools even when formal curricular provision is nominally identical across regions (Habibi et al., 2020; Nugraha & Bajari, 2022). It also resonates with international research showing that policy reforms intended to standardize educational quality frequently generate divergent implementation experiences between urban and rural or frontier settings (Baharuddin & Burhan, 2025; Gunawan et al., 2025), undermining the assumption that uniform policy produces uniform opportunity.

Rethinking Curriculum Implementation Through Students' Voices

Evaluations of curriculum implementation have traditionally centered on teachers, school leaders, policy documents, facilities, and assessment outcomes, leaving students themselves comparatively underexamined as sources of evidence. This study offers a distinct perspective by positioning students as interpreters of curriculum implementation. When students report that the curriculum emphasizes inquiry, observation, and experimentation, yet indicate that they rarely experience these forms of engagement in practice, their accounts provide direct evidence of a gap between the intended curriculum and the curriculum as experienced in the classroom. The findings further suggest a sequential relationship in which the intended curriculum is translated into classroom implementation, experienced by students, interpreted through their meaning-making processes, and subsequently negotiated through their learning experiences. This analytical sequence positions student testimony as a distinct source of evidence on the experienced curriculum and students' opportunities to learn, complementing rather than substituting for teacher and policy focused evaluations, which remain necessary for assessing fidelity to the intended curriculum. By foregrounding students' lived experiences, this perspective reveals how curricular expectations are actually enacted, interpreted, and negotiated within everyday classroom contexts. This approach is consistent with emerging international scholarship on student voice in curriculum reform, which argues that students are frequently positioned as passive evaluators rather than active informants or participants in curriculum-related research and policymaking, despite their unique epistemic access to the lived experience of implementation.

The findings suggest that curriculum policy for frontier regions should move beyond specifying minimum content coverage toward guaranteeing minimum learning opportunities. This requires contextual flexibility in how national standards are translated into classroom practice, differentiated implementation guidance for geographically isolated schools, and realistic expectations calibrated to the material conditions documented in this study, rather than uniform benchmarks that assume equal infrastructural capacity (Tutal, 2026). Teachers in frontier schools would benefit from structured support in designing environment-based inquiry and low cost experiments of the kind students in this study already improvised informally, from professional development that legitimizes and systematizes improvisation as a recognized pedagogical strategy rather than an ad hoc workaround (Dhurumraj & Moola, 2023; Mabasa & Singh, 2020), and from adaptive, contextually responsive use of digital technology where connectivity permits.

Schools may benefit from strengthening the peer learning structures that students in this study already relied upon, formalizing resource sharing arrangements, and building partnerships with surrounding communities to draw more systematically on local ecological knowledge as an instructional resource (Ala & Antonio, 2026; Sutomo & Siregar, 2022). At the policy level, the central question guiding evaluation should shift from "Does every school implement the same curriculum?" to "Does every student have a meaningful opportunity to experience the learning that the curriculum promises?" This reframing is essential if curricular standardization is not to mask persistent and geographically patterned inequities in learning opportunity.

This study makes three interrelated contributions. Empirically, it provides direct evidence from students' testimonies of how curriculum implementation is experienced in frontier science classrooms in Indonesia's outer regions, a population and perspective still underrepresented in curriculum implementation research (Nugraha & Bajari, 2022). Conceptually, it reframes the curriculum–practice gap as an interaction among curricular expectations, structural constraints, classroom practices, student perceptions, and agency, rather than as a simple implementation failure attributable to a single actor. This perspective integrates and extends opportunity-to-learn theory (Perry et al., 2024), asset-based and funds-of-knowledge perspectives on marginalized learners (Denton & Borrego, 2021; Moll, 2019), and student agency theory Inouye et al., 2023) within a new national and geographical context. Methodologically, the study demonstrates the value of treating students' voices as primary evidence of the consequences of curriculum implementation, complementing teacher- and policy-centered approaches through rigorous reflexive thematic analysis.

CONCLUSION

This study set out to answer two research questions concerning students' experience of the curriculum practice gap in Indonesia's frontier science education and the ways learning hurdles shape their perceptions of science and their strategies for persistence. In response to the first question, the findings demonstrate that students in frontier settings do not experience a wholesale divergence from the national science curriculum, rather they experience a narrowing of the experiential, laboratory-based, and inquiry-oriented opportunities through which that curriculum is meant to be enacted, producing an opportunity-to-learn gap rather than a content gap. In response to the second question, the findings reveal that these hurdles carry a double-edged consequence. They can generate frustration and a perception of science as abstract, distant, or based memorization, yet the same constraints, when successfully negotiated, can also reposition science as observable in everyday environments. Students sustained their educational progress not as passive recipients of disadvantage but as active negotiators who mobilized peer collaboration, digital resources, teacher consultation, and locally available materials to construct alternative pathways to learning.

These findings carry implications for curriculum policy and teacher practice. For policy, the findings suggest that standardized national curricula require contextually responsive, rather than uniform, pathways of implementation in frontier regions, and that policy attention should shift from ensuring uniform curriculum content toward guaranteeing equitable minimum learning opportunities. For practice, the findings suggest that students' own testimony constitutes a valuable, underused source of evidence on the experienced curriculum and students' opportunities to learn, complementing rather than replacing teacher and policy focused evaluation. For future research, subsequent studies should incorporate multi stakeholder perspectives spanning teachers, school leaders, and policymakers, employ comparative frontier urban designs, and test locally contextualized, low cost experimentation through intervention studies. This study is limited by its reliance on student self report from 10 students across 10 schools in Southwest Papua Province, without corroborating classroom observation, teacher interviews, or curriculum document analysis. Its findings should therefore be read as an in depth, contextually grounded account of these students' experiences rather than as statistically representative or generalizable to junior secondary students across Indonesia's frontier regions more broadly.

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