Science Teacher Educators' Perceptions of Science Education in Indonesia: Challenges, Systemic Barriers, and Pedagogical Gaps

Persepsi Pendidik Guru Sains terhadap Pendidikan Sains di Indonesia: Tantangan, Hambatan Sistemik, dan Kesenjangan Pedagogis

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Abstract: *Science education in Indonesia continues to grapple with systemic and persistent challenges, particularly regarding teacher quality and the overall effectiveness of science teaching and learning. This study aims to examine Science Teacher Educators' (STEs) perceptions of the current state of science education in Indonesia, the key challenges affecting its development, as well as the systemic factors influencing teacher preparation and classroom practice. Using a qualitative research design, semi-structured interviews were conducted with 19 STEs from a leading university in science education in Bandung, West Java, Indonesia. The data were analyzed using thematic analysis. The findings reveal that STEs perceived science education in Indonesia as still facing interconnected challenges, including inconsistent teacher professionalism, disparities in the quality of teacher preparation across institutions, limited opportunities for practical and inquiry-based learning, frequent curriculum changes without sustained policy direction, and skepticism toward international assessments. Overall, these findings highlight the complex interplay among institutional, policy, and cultural factors shaping science education in Indonesia and underscore the need to strengthen teacher education as a key strategy to improve the quality of science education.*

Keywords: *science education; science teacher educators; teacher preparation; inquiry-based learning; education policy*

Abstrak: *Pendidikan sains di Indonesia terus menghadapi tantangan yang bersifat sistemik dan berkelanjutan, khususnya terkait dengan kualitas guru dan efektivitas pembelajaran sains secara keseluruhan. Penelitian ini bertujuan untuk mengkaji persepsi pendidik guru sains (dosen) terhadap kondisi pendidikan sains di Indonesia saat ini, tantangan utama yang memengaruhi perkembangannya, serta faktor sistemik yang memengaruhi persiapan guru dan praktik pembelajaran di kelas. Penelitian ini menggunakan desain penelitian kualitatif, dengan data yang dikumpulkan melalui wawancara semi-terstruktur terhadap 19 dosen pendidik guru sains dari salah satu universitas terkemuka dalam bidang pendidikan sains di Bandung, Jawa Barat, Indonesia. Data dianalisis menggunakan analisis tematik. Hasil penelitian mengungkapkan bahwa para pendidik guru sains mempersepsikan pendidikan sains di Indonesia masih menghadapi tantangan yang saling terkait,* *meliputi profesionalisme guru yang belum konsisten, kesenjangan kualitas pendidikan calon guru antarinstitusi, terbatasnya kesempatan untuk pembelajaran praktikum dan berbasis inkuiri, perubahan kurikulum yang sering terjadi tanpa arah kebijakan yang berkelanjutan, serta adanya skeptisisme terhadap asesmen internasional. Secara keseluruhan, temuan ini menyoroti kompleksitas keterkaitan antara faktor kelembagaan, kebijakan, dan budaya yang membentuk wajah pendidikan sains di Indonesia serta menegaskan pentingnya penguatan pendidikan guru sebagai strategi utama untuk meningkatkan kualitas pendidikan sains.*

Kata kunci: *pendidikan sains; pendidik guru sains; pendidikan calon guru; pembelajaran berbasis inkuiri; kebijakan pendidikan*

INTRODUCTION

Science education plays a key role in equipping individuals to engage critically with the scientific, technological, and environmental challenges in modern society. It equips students with the knowledge, skills, and values required for informed decision-making and for active participation in an increasingly knowledge-based global society (Carter, 2008; Psillos, 2003; Vali, 2013). Some previous research indicates that high-quality science teaching can promote and encourage scientific literacy, curiosity, and problem-solving, which are essential competencies for sustainable development and innovation (Buchanan, 2024; H. Kang et al., 2016; Kaptan & Timurlenk, 2012). Furthermore, science education contributes to students' ability to apply scientific reasoning to real-world problems and strengthens their capacity to live as lifelong learners and to engage in civic life (Levy et al., 2021; Teshera-Levye et al., 2025). Despite its importance, many countries, particularly developing countries in the Global South such as Indonesia, continue to face major challenges related to educational quality, teacher competence, and the implementation of inquiry-based science learning, highlighting the urgency of improving science education systems (Fitzgerald et al., 2019; Ogegbo et al., 2024; Strat et al., 2024)

In the global context, international assessments such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) have revealed wide disparities in students' science achievement. The outcomes of these assessments have become a significant benchmark that influences educational policies in many developing countries, as the results often expose systemic weaknesses in teacher preparation, curriculum design, and institutional support (Rutkowski et al., 2020). Indonesia provides an instructive example. Despite continuous educational transformations, the students consistently perform below the international average in science (OECD, 2023; Setiawan et al., 2024). The 2022 PISA results showed that many Indonesian students struggled to apply scientific concepts and reasoning skills, indicating persistent weaknesses in science teaching and learning (OECD, 2023). In the Indonesian context, science education refers to science instruction at the elementary, junior high, and senior high school levels, including integrated science at the elementary and junior high school levels and separate subjects such as Physics, Chemistry, and Biology at the senior high school level. Therefore, challenges in science education must be understood across these levels of schooling, not only at the university level.

Over the last few decades, at the school level, Indonesia has introduced multiple reforms aimed at improving educational quality, especially curriculum reforms such as the *Kurikulum* 2013 [The 2013 Curriculum] and the *Kurikulum Merdeka* [Emancipated Curriculum] initiative. These policies were designed to promote student-centered, inquiry-based instruction and to empower teachers to innovate in the classroom (Mahyuna et al., 2024; Suharyanto et al., 2014). However, their implementation has often been inconsistent, hampered by limited resources, variable teacher competence, and weak institutional support (Paraniti & Suma, 2022; Yusa et al., 2023). Many science classrooms remain dominated by traditional, lecture-based approaches rather than active, inquiry-oriented methods. Furthermore, curriculum changes without sustainable follow-up mechanisms have created challenges among teachers in adapting to reforms and may potentially limit the long-term impact of educational reform (Paraniti & Suma, 2022; Yusa et al., 2023). These conditions suggest that improving science education requires not only curriculum reform but also strengthening teacher preparation and teacher education institutions.

The issue of teacher quality lies at the center of these challenges. Teacher competence and professional commitment are among the strongest predictors of student learning outcomes (Qodriyani et al., 2020). However, the quality of teacher preparation in Indonesia varies widely across institutions, with differences in facilities, staff expertise, and research engagement (Head Foundation, 2020). Teacher certification programs and professional development initiatives have attempted to address these disparities, but many remain procedural, focusing more on administrative compliance than on reflective practice or pedagogical improvement (Kurniadi, 2025). In many cases, teachers lack opportunities for continuous learning or mentorship that would help them integrate innovative, inquiry-based approaches into classroom instruction (Risa & Madani, 2024).

At the heart of improving teacher quality are Teacher Educators (TEs), specifically Science Teacher Educators (STEs) in science education, academics who prepare science teachers and guide the professional growth of both current and future science teachers (Nugraha et al., 2024). STEs play an essential role in shaping preservice teachers' understanding of scientific concepts, pedagogical reasoning, and classroom practice (Nugraha et al., 2024). Through their education and mentoring, STEs influence how new teachers interpret curricula and design learning experiences for students (Loughran & Menter, 2019). Despite this central role, the voices and experiences of Indonesian STEs are underrepresented in both national and international research (Nugraha, 2025). Understanding how STEs perceive the state of science education and the challenges within their professional context is therefore crucial for improving science teacher education and, ultimately, science learning outcomes. However, existing research on science education in Indonesia has largely focused on students, teachers, curriculum, or instructional methods, while STE as a profession remains underexplored, particularly regarding how they perceive systemic challenges in science education and teacher preparation. This represents a significant gap in the literature because STEs play a central role in shaping teacher competence and instructional practices.

Systemic and institutional factors further shape the landscape of science education. Policy instability has long been identified as a barrier to sustainable reform in Indonesia, where changes in political leadership often result in new curriculum frameworks and evaluation systems (Paraniti & Suma, 2022; Yusa et al., 2023). These shifts, while intended to modernize education, often lack coherence and continuity. Teachers and TEs must repeatedly adapt to new standards and terminologies, which can undermine long-term planning and professional consistency (Head Foundation, 2020; Yusa et al., 2023). The decentralization of education governance has also led to uneven policy implementation across regions, contributing to disparities in resource allocation and training opportunities (Head Foundation, 2020; Yusa et al., 2023).

Amid these challenges, STEs occupy a strategic position. They are both products and agents of the education system, navigating its complexities while seeking to prepare future teachers who can improve it (Loughran & Menter, 2019). Their perspectives offer valuable insight into how institutional, policy, and cultural conditions shape teacher preparation and professional identity (Nugraha, 2025). However, limited research has examined their views in the Indonesian context (Nugraha et al., 2024). Most existing studies have focused on teachers or students, overlooking the voices of those who shape the next generation of science educators (Nugraha, 2025). Therefore, understanding STEs' perspectives is important to provide a more comprehensive understanding of science education reform and teacher education in Indonesia.

Based on this gap, this study aims to explore STEs' perceptions of the current state of science education in Indonesia, the major challenges affecting science teaching and learning, and the systemic factors influencing teacher preparation and classroom practice. This study is expected to contribute to the literature by providing empirical evidence on STEs' perspectives in the Indonesian context and by offering practical recommendations for universities, policymakers, and teacher education institutions to improve science teacher education and science education policy.

The research is guided by three key questions: (1) How do Indonesian STEs perceive the current quality and challenges of science education in Indonesia? (2) What systemic factors do they identify as influencing science education practices and outcomes? and (3) How do they describe the relationship between university-based teacher education programs and classroom practices in schools?

METHODS

Research Design

This study employed a qualitative interpretive approach to explore Indonesian STEs' perceptions of science education quality, systemic challenges, and the connection between teacher education and school practice. A qualitative design was considered appropriate for examining complex educational realities through participants' lived experiences and professional interpretations (Creswell & Creswell, 2017). This approach enabled an understanding of how STEs make sense of the institutional, policy, and cultural factors shaping the quality of science education in Indonesia.

Research Site and Time

The research was conducted at a teacher education university in Bandung, West Java, Indonesia, within the Faculty of Mathematics and Science Education, from July to August 2023. This faculty was selected because it represents a comprehensive teacher education environment and is part of a leading university in education in Indonesia. The faculty offers undergraduate and postgraduate programs in biology, chemistry, physics, and general science education, and plays a central role in shaping future science teachers. The institution was therefore an appropriate site to explore how STEs perceive the state of science education and the factors influencing its quality.

Participants

A total of 19 faculty members voluntarily participated in the study. They represented various science disciplines (biology, chemistry, physics, and general science education) and career stages, including early-, mid-, and late-career academics (Table 1). Some participants held doctoral degrees from overseas institutions, while others were trained domestically, offering a variety of academic and pedagogical viewpoints that reflected both global and local experiences. All participants were invited voluntarily and provided written informed consent before participation. They were told that their identities would remain confidential and that pseudonyms would be used throughout the research process. In this case, STE and the identifier used to identify the STEs, such as STE1, indicate STE 1. Participants were also assured that they could withdraw from the study at any time without penalty.

Research Instrument and Validation

The main research instrument used in this study was a semi-structured interview guide inspired by Indonesian PISA results (OECD, 2023). The interview guide was designed to explore STEs' perceptions of science education in Indonesia, the challenges affecting science teaching and learning, and the systemic factors influencing teacher preparation and science education outcomes. The semi-structured format allowed the researcher to ask predetermined questions while also providing flexibility to explore participants'

Table 1. Interviewees' Characteristics

Name	Gender	Academic background	Academic Tittle	Career Stages/ Years of Working Experience
STE1	Male	Master in Science Education	Associate Lecturer	Early Career (Less than 7 years)
STE2	Female	Master in Science Education	Associate Lecturer	Early Career (Less than 7 years)
STE3	Female	Master in Science Education	Associate Lecturer	Early Career (Less than 7 years)
STE4	Male	Master in Science	Lecturer	Early Career (Less than 7 years)
STE5	Female	Master in Science	Associate Lecturer	Early Career (Less than 7 years)
STE6	Female	Master in Science	Associate Lecturer	Early Career (Less than 7 years)
STE7	Male	Master in Science Education	Associate Professor	Mid-Career (7 to 20 years)
STE8	Female	Master in Science Education	Senior Lecturer	Mid-Career (7 to 20 years)
STE9	Female	Master in Science Education	Senior Lecturer	Mid-Career (7 to 20 years)
STE10	Male	Doctor in Science Education	Senior Lecturer	Mid-Career (7 to 20 years)
STE11	Male	Doctor in Science	Associate Professor	Mid-Career (7 to 20 years)
STE12	Male	Doctor in Science Education	Senior Lecturer	Mid-Career (7 to 20 years)
STE13	Male	Doctor in Science Education	Professor	Late Career (More than 20 years)
STE14	Male	Doctor in Science Education	Associate Professor	Late Career (More than 20 years)
STE15	Male	Doctor in Science	Professor	Late Career (More than 20 years)
STE16	Female	Doctor in Science Education	Associate Professor	Late Career (More than 20 years)
STE17	Female	Doctor in Science Education	Professor	Late Career (More than 20 years)
STE18	Male	Doctor in Science	Professor	Late Career (More than 20 years)
STE19	Male	Doctor in Science Education	Associate Professor	Late Career (More than 20 years)

responses in greater depth through probing questions. The interview guide consisted of three main sections: (1) perceptions of science education quality, (2) challenges in science teaching and learning, and (3) systemic factors affecting teacher preparation and science education. Each section included several open-ended questions and probing questions to encourage participants to elaborate on their experiences and perspectives. The structure of the interview guide is presented in Table 2.

To ensure content validity, the interview guide was reviewed by three experts in educational research and qualitative research. The experts evaluated the relevance of the questions, the clarity of the wording, and the alignment between the interview questions and the research objectives. Revisions were made based on their feedback, particularly to improve clarity, avoid leading questions, and ensure that the questions could generate in-depth responses.

A pilot interview was conducted with two STEs who were not included in the main study participants. The purpose of the pilot interview was to evaluate the clarity, sequence, and duration of the interview questions. The pilot interview indicated that the questions were understandable and generated rich, relevant data. Therefore, the interview guide was considered appropriate for data collection.

Table 2. Summary of Semi-Structured Interview Instrument

Section	Focus	Example Questions	Purpose
Section A	Perceptions of science education quality	How do you perceive the current quality of science education in Indonesia?	To explore STEs' views on the overall condition of science education
Section B	Challenges in science teaching and learning	What are the biggest challenges faced by science teachers in Indonesia?	To identify major challenges in science teaching and learning
Section C	Systemic factors affecting teacher preparation and science education	How do you see the role of universities in preparing science teachers?	To explore systemic and institutional factors influencing science education
Closing	Reflection and recommendations	What should be improved to improve science education in Indonesia?	To identify suggested improvements and future directions

Data Collection and Analysis

Data were collected through semi-structured interviews designed to capture in-depth, reflective accounts of participants' experiences and professional reasoning. This method was chosen because it provides flexibility while ensuring focus on key research issues (Creswell & Creswell, 2017). The interview protocol was informed by previous literature on teacher education, science pedagogy, and education reform (Cohen et al., 2002). The interviews encouraged participants to share their perceptions of the quality of science education in Indonesia, identify key challenges in teaching and learning, and discuss systemic factors affecting teacher preparation and science achievement. Interviews were conducted in Indonesian, online via secure video conferencing platforms. Each interview lasted approximately 45 to 75 minutes and was video-recorded with permission. Field notes were taken during and immediately after each interview to record contextual information, such as tone, pauses, and reflections, which could aid later interpretation.

All interviews were transcribed verbatim, and transcripts were carefully translated into English to facilitate analysis and ensure broader accessibility. Translation accuracy was prioritized through multiple cross-checks of transcripts to maintain the original meaning and nuance of participants' expressions. Clarification was sought directly from participants when linguistic or cultural ambiguities arose to ensure that interpretations remained authentic and credible.

Data were analyzed using thematic analysis (Guest et al., 2011). This approach was selected because it enables the identification and interpretation of recurring patterns and meanings in qualitative data. The analysis process involved iterative reading and re-reading of the transcripts to familiarise the researcher with the content. Inductive coding was used to generate preliminary codes that reflected participants' experiences, ideas, and concerns about the quality of science education and its systemic challenges (Morrell & Carroll, 2010). Similar codes were grouped to form initial categories, which were refined continuously as the analysis progressed. Themes were then defined and named to capture their central meaning. NVivo 12 software supported data management, helping to organize codes and facilitate the identification of thematic connections. Each researcher independently reviewed the interview data and coded it based on the identified themes. Afterward, both researchers jointly examined the entire set of coded interviews to confirm mutual agreement on which interview segments corresponded to each theme (Guest et al., 2011).

Trustworthiness

To ensure the rigor and trustworthiness of the findings, the study employed strategies consistent with the established framework of credibility, dependability, confirmability, and transferability (Lincoln & Guba, 1985). Credibility was strengthened through member checking, whereby participants reviewed summaries of their transcripts and interpretations to verify accuracy and authenticity. Dependability was maintained by systematically documenting the research process, coding decisions, and analytical reflections in an audit trail, thereby providing transparency and consistency across the analysis stages (Nowell et al., 2017). Confirmability was reinforced through peer debriefing sessions with academic colleagues to minimize researcher bias and ensure that findings were grounded in participants' accounts rather than the researcher's assumptions (Tisdell et al., 2025). Finally, transferability was supported by providing detailed descriptions of the research methods, participants, and procedures, enabling readers to evaluate the applicability of findings to other educational settings.

RESULTS AND DISCUSSION

The analysis of STE's interview data revealed seven interconnected themes concerning the quality of Indonesian science education: (1) variation in teacher quality and preparation, (2) weakness in science literacy and practice, (3) structural and economic constraints, (4) policy instability and weak governance, (5) cultural and attitudinal barriers, (6) STEs as agents of change, and (7) broader systemic and socioeconomic influences. Together, these themes provide a nuanced picture of how STEs perceive the current state of science education and the systemic conditions that shape its outcomes.

Variation in Teacher Quality and Preparation

A central theme emerging from the interviews was the variation in teacher quality and the inconsistency of teacher preparation programs across Indonesia. Many participants pointed out that teacher competence depends heavily on individual motivation, institutional quality, and the extent of practical preparation. As one educator stated, "Technically, teachers who graduate from universities are equipped with the ability to teach science, but when they work in schools, the quality of their teaching really depends on each teacher. Some prepare very well, but some only rely on textbooks and do not update themselves with the latest scientific developments" (STE1).

Several STEs attributed this inconsistency to the lack of standardization among teacher education institutions. One participant remarked, "The standard curriculum for science teacher education is not standardized throughout Indonesia, so the quality of teachers produced varies greatly. Teachers in big cities who graduate from the best universities are different from those in underdeveloped areas who graduate from lower-ranked campuses" (STE6). Another noted that "the number of campuses producing teachers is enormous, like mushrooms. There needs to be strict standardization to ensure only qualified universities produce science teachers" (STE17).

According to participants, these disparities result in uneven levels of teaching competence across schools. The absence of strong national regulation and quality assurance mechanisms has allowed some institutions to focus more on quantity than quality. Several participants expressed concern that teacher certification and training have little long-term impact. "Teacher certification does not have a visible effect after several years because there is no proper mechanism to monitor performance," said one respondent (STE13). Collectively, these accounts suggest that unequal quality in teacher education remains a fundamental issue affecting national science learning outcomes.

The uneven quality of teacher education was attributed by participants to differences in institutional capacity, curriculum standards, and quality assurance. This echoes earlier research showing that decentralized teacher education systems often produce inconsistent outcomes when national frameworks are weak (Jalal et al., 2009; Revina, 2022). Participants' concerns that teacher competence depends heavily on personal motivation and institutional prestige illustrate the risks of expanding teacher education without parallel investment in quality control. Similar issues have been noted across Southeast Asia, where rapid expansion has prioritized access over rigor (Kusumawardhani, 2017). In Indonesia, the proliferation of teacher education institutions has led to variations in graduate quality, reflecting the absence of uniform accreditation and evaluation mechanisms (Irnidayanti & Fadhilah, 2023). These findings reaffirm that national regulation and accreditation are critical to ensuring consistency in teacher preparation and professional standards (Rahmi & Rassanjani, 2025).

Beyond institutional differences, this finding reflects a systemic issue in Indonesia's teacher workforce policy. Indonesia needs to adapt to a system applied in countries with robust education systems, such as Singapore, China, North America, and Scandinavian countries, which generally feature selective teacher education programs, substantial practicum components, and stringent accreditation systems to guarantee teacher readiness (Doil & Pietzner, 2023; Tonga et al., 2022; Zhang et al., 2024). The selection process for teacher candidates is highly selective, ensuring that only the most qualified candidates are accepted into teacher education programs, followed by continuous professional development programs. This is in stark contrast to the situation in Indonesia, where admission to and preparation for teacher education remain less selective and more variable across institutions. Improving the quality of science education requires strengthening teacher education accreditation, practicum programs, and monitoring systems for teacher certification and professional development. Policies such as teacher certification and professional allowances may improve teacher welfare, but without continuous professional development and performance evaluation, they have a limited impact on teaching quality. Continuous professional development and mentoring, particularly for early-career teachers, are more strongly associated with improvements in teacher competence and instructional quality (Kim, 2026). Therefore, education policy should shift from a primary focus on certification to one that prioritizes continuous professional development, performance evaluation, and mentoring systems.

Weakness in Science Literacy and Practice

Most STEs agreed that science learning in Indonesia remains dominated by rote memorization and theoretical orientation, resulting in low levels of scientific literacy. They observed that science classes often prioritize completing textbook content over promoting inquiry or practical learning. "Science learning has not changed much for decades. Teachers focus on the contents of textbooks and on drilling students for exams, rather than teaching the essence of science," said one participant (STE7).

This lack of emphasis on inquiry-based learning was seen as particularly damaging to students' higher-order thinking skills. One educator explained, "I found that many students entering university still struggle to make graphs or tables. Their logical and analytical skills are weak. They remember content, but when it's applied in another context, they face difficulties" (STE4).

Participants frequently linked poor science literacy to the limited use of laboratories and practical work in schools. As one senior STE noted, "In our schools, laboratory facilities are worrying, and it is rare for students to learn by doing. Most science learning is reading books and taking exams" (STE12). The problem, they argued, begins in schools and continues into teacher education programs, where prospective teachers themselves have limited experience with experimental or inquiry-based learning.

Several participants lamented that the abolition of the national examination had seriously reduced students' motivation to study science. "Since there's no national exam, students' motivation to learn science has dropped. They are less serious, and even prospective science teachers now enter with poor science skills and minimal practicum experience" (STE13). These findings reflect a systemic disconnect between curricular ideals and classroom realities, with practical and inquiry-based science learning remaining largely aspirational.

The persistence of rote learning and limited inquiry-based practice remains a central challenge in Indonesian science education (Gumilar et al., 2019). STEs noted that while students can memorize facts, they often struggle to apply concepts, reflecting PISA 2022 findings of weak scientific reasoning among Indonesian learners (OECD, 2023). Science instruction continues to emphasize factual recall rather than fostering critical thinking and problem-solving, partly due to inadequate teacher training and limited access to laboratory facilities (Saekawati & Nasrudin, 2021). Although inquiry-based approaches are recognized for improving students' conceptual understanding and scientific attitudes (Gumilar et al., 2019). Their adoption in classrooms remains inconsistent and largely aspirational. Without institutional and policy support for practical experimentation and professional development, reforms promoting inquiry-oriented pedagogy are unlikely to translate into sustained classroom change.

The weakness in scientific literacy does not solely stem from students' abilities; instructional practices, assessment systems, and teacher preparation also strongly influence it. Research shows that scientific literacy is closely related to how science is taught, particularly through inquiry-based and student-centered learning approaches rather than traditional content transmission (Kang, 2022). Inquiry-based science teaching requires teachers to have strong pedagogical content knowledge (PCK), classroom management skills for practical work, and sufficient professional development support to implement inquiry effectively (Aidoo, 2024). In addition, unsupported assessment practices are a major barrier to effective inquiry-based science teaching and the development of scientific literacy (Hung & Wu, 2024). From a policy perspective, improving scientific literacy requires systemic reform that includes strengthening science teachers' pedagogical content knowledge (PCK) in university-based teacher education and aligning curriculum, assessment, and professional development systems with the goals of scientific literacy, rather than placing responsibility primarily on students. Furthermore, policy reform must address structural inequalities by ensuring equitable access to quality learning infrastructure, particularly science laboratories, across schools in Indonesia.

Structural and Economic Constraints

Economic disparities and structural challenges were consistently cited as key barriers to quality science education. Many STEs emphasized that teacher welfare and school resources directly affect teaching quality and motivation. "Teacher salaries are very influential. In private or international schools, science learning is perceived very good because teachers' salaries are guaranteed so that they can focus on their work," explained one participant (STE8). Another added, "There's a clear difference between schools. In private schools, the facilities and welfare are better, while in public schools, teachers are burdened by administrative responsibilities and large class sizes, making instructional innovation difficult" (STE10).

Participants frequently described how financial constraints limit teachers' ability to improve their professional competence. "Teachers want to teach well, but their income is not enough compared to the effort they must put in. Their energy is not balanced with their welfare," observed one respondent (STE15). Several STEs also highlighted the imbalance between teaching demands and institutional support. "We often conduct teacher training, but in practice, teachers tend to return to their old habits because there is little follow-up monitoring," said another (STE6).

These accounts underscore the strong relationship among economic well-being, motivation, and the quality of science teaching. Some educators even argued that improving the nation's economy is a prerequisite for raising science achievement. "If we look at countries with strong economies, their scientific achievements are also high. The government should focus on improving teacher prosperity so that they can perform their duties professionally," argued one STE (STE12).

The interviews underscore the strong link between teacher welfare, institutional resources, and teaching quality. Many participants described how low salaries, administrative burdens, and resource shortages constrain teachers' motivation and creativity (Murwaningsih, 2024). This finding supports evidence that professional satisfaction and economic stability are foundational to teacher engagement (Melliofatria et al., 2022). The disparity between private and public schools, and between urban and rural contexts, mirrors broader socioeconomic inequalities that shape educational outcomes (Nuraeni et al., 2024). These inequities not only hinder innovation but also reinforce cycles of underperformance in disadvantaged regions (Maulana, 2021).

From a teacher welfare perspective, Indonesia continues to face a long-standing structural issue, namely low salaries for honorary teachers, who constitute more than 50% of the teaching workfoce in Indonesia. (Sabon, 2022). This condition reflects systemic inequality within the teacher employment system and has implications for teacher motivation, retention, and teaching quality. The aforementioned phenomena explain why many professional development programs do not lead to sustained changes in classroom practice, as economic and structural constraints limit teachers' ability to implement new teaching approaches. The data suggest that efforts to reform science education must be accompanied by structural improvements in teacher welfare and equitable resource distribution (Melliofatria et al., 2022; Murwaningsih, 2024). Improving science education requires structural policy reform, including improving teacher welfare, reducing administrative workload, improving school infrastructure, and ensuring equitable distribution of educational resources.

Policy Instability and Weak Governance

Another major concern expressed by participants was the instability of education policy and the lack of consistent direction in curriculum implementation. Many respondents noted that frequent changes in educational leadership lead to shifts in curriculum focus, resulting in challenges and uncertainty among teachers in adapting to new policies. "Changes in educational leadership tend to be accompanied by curriculum reforms. A sustainable vision for education remains a challenge in this country," remarked one participant (STE13).

Participants also criticized the top-down nature of education policy, which often excludes practitioners from decision-making. "Policies are designed at the top without consulting those who teach. As a result, schools just follow orders without understanding the rationale," explained another educator (STE16).

Some participants linked these issues to weak governance and poor accountability mechanisms. "The direction of education is unclear. School teachers can't do much; they follow whatever the government decides," said one senior STE (STE13). Many agreed that stronger collaboration among policymakers, universities, and schools is necessary to create sustainable reforms. As one mid-career educator put it, "We need consistent policies supported by long-term planning, not just temporary projects that end when leadership changes" (STE6).

Participants' frustration with frequent policy changes and top-down decision-making reflects systemic governance weaknesses in Indonesian education. The tendency for each ministerial change to produce a new curriculum disrupts continuity. It erodes teachers' confidence in reform, a pattern also observed in other developing contexts where political turnover fragments reform agendas (Velthuis et al., 2021). Moreover, the exclusion of practitioners from policymaking contributes to a sense of detachment, making policies appear disconnected from classroom realities. Such disconnection aligns with findings that curriculum reforms are often imposed without adequate consultation or shared understanding among educators, leading to superficial implementation and limited ownership (Matiki et al., 2023). The STEs' call for stronger collaboration between universities, schools, and government institutions underscores the need for distributed leadership and shared accountability to ensure sustainable, contextually grounded policy development. Therefore, education reform should focus on policy consistency, long-term planning, and greater involvement of teachers and TEs in policy making to ensure that reforms are realistic and sustainable.

Cultural and Attitudinal Barriers

Several STEs identified cultural and attitudinal factors as underlying barriers to improving the quality of science education. Participants described a "comfort zone" mentality among teachers, referring to resistance to innovation or change. "Teachers often feel comfortable with old methods and are reluctant to upgrade their abilities. They hand over tasks to new teachers instead of learning together," said one respondent (STE11).

Others emphasized that societal attitudes toward the teaching profession contribute to the low quality of incoming teacher candidates. "Top students don't want to become teachers because the job isn't prestigious and the income is low. They prefer other professions such as medicine or law," noted one senior educator (STE13). Another echoed this sentiment "If teaching were a prestigious profession, the best young people would want to become teachers" (STE13).

Participants also described traditional classroom hierarchies in which students rarely question teachers, thereby limiting active engagement. These ingrained cultural attitudes, combined with limited incentives for innovation, hinder the transformation of science education practices. One participant concluded, "Teachers teach in the way that is easiest for them, not necessarily the best way for students. They focus on finishing material rather than developing inquiry" (STE14).

Deeply rooted cultural norms present additional challenges to science education reform in Indonesia. Participants described hierarchical classroom relationships that discourage questioning and experimentation, consistent with the "transmission model" of science teaching (Osborne & Dillon, 2008). Such norms, coupled with the low societal valuation of the teaching profession, reduce the appeal of teaching for high-achieving students (Suryani, 2021). Furthermore, teachers' reluctance to adopt new pedagogical approaches often reflects a lack of institutional incentives and recognition for continuous professional learning (Irnidayanti & Fadhilah, 2023; Kusumawardhani, 2017; Melliofatria et al., 2022; Murwaningsih, 2024). These findings underscore that meaningful reform requires not only curriculum and training redesign but also a broader cultural transformation that values reflection, collaboration, and experimentation in both teaching and learning.

Science Teacher Educators as Agents of Change

Despite these challenges, many STEs viewed themselves as key agents for transforming science education. Participants consistently expressed a professional commitment to improving the quality of science teaching through modelling, mentoring, and advocacy. "I feel responsible because the quality of teachers is determined by us who produce them. I always try to model good science teaching, just as my lecturers once did for me," said one educator (STE5).

Others described efforts to instil reflective and inquiry-based thinking among pre-service teachers. "We train our students with inquiry approaches, but when they go to schools, the teachers there often revert to traditional methods. That's a gap we must bridge," noted another (STE14). Despite recognizing institutional limitations, several participants emphasized that small-scale change can still make a difference. "Even if the system is weak, we can start by changing our own teaching. That's where transformation begins," shared one early-career STE (STE7).

Participants also called for stronger collaboration among STEs to influence education policy. "We need to work together across universities to strengthen our voice. Teacher educators must contribute ideas to reform policy and improve science education quality," explained one senior educator (STE18). These statements reflect a strong sense of agency and professional identity among STEs, who see their role extending beyond teacher preparation to educational reform.

Despite systemic challenges, STEs in this study demonstrated strong professional agency and moral commitment to improving science education. Their emphasis on modelling, mentoring, and advocacy reflects the argument that TEs play a dual role as both teachers and exemplars of good practice (Loughran, 2013). Participants' efforts to cultivate inquiry-based pedagogy and reflective thinking among pre-service teachers show that reform can begin at the micro level of teacher preparation, consistent with the notion of "grassroots reform", where small-scale, locally driven initiatives can collectively influence broader systemic change (Fullan, 2016). Moreover, participants' calls for collaboration among STEs across institutions reveal an emerging sense of professional solidarity that could strengthen their collective voice in shaping national education policy. This aligns with the view that empowering teacher educators as "knowledge brokers", those who connect research, practice, and policy, is essential for translating reform agendas into meaningful classroom practice (Lunenberg et al., 2014). Similar perspectives have been echoed internationally, suggesting that a shared professional identity among TEs is foundational for systemic improvement in teacher education (Goodwin & Kosnik, 2013). TEs, specifically STEs, can also serve as bridges among education research, policy, and classroom practice. In this case, education policy should involve teacher educators more actively in curriculum development, teacher professional development programs, and education policy planning.

Broader Systemic and Socioeconomic Influences

Finally, participants acknowledged that the challenges facing science education in Indonesia cannot be separated from broader socioeconomic conditions. Regional inequality, limited infrastructure, and social disparities were frequently cited as underlying causes of poor science performance. "In small or rural campuses, the facilities to produce quality science teachers are far below standard. In neighbouring countries, only large universities with adequate facilities are allowed to produce teachers," said one educator (STE19).

Others noted the direct link between social inequality and student learning outcomes. "In rural areas, students have minimal access to laboratory facilities, yet they are tested under the same national standards as students in big cities," observed one participant (STE10). Another summarised, "Science learning is not only about schools but also about social conditions. When students face poverty or lack resources, science becomes secondary" (STE19).

These reflections indicate that improving the quality of science education requires holistic reform that encompasses economic, social, and infrastructural development. As one educator put it, "Education and economy cannot be separated. Only when teachers and schools are supported can science education improve" (STE12).

Finally, participants acknowledged that educational improvement cannot be separated from broader social and economic development, as regional inequality, limited infrastructure, and poverty were repeatedly identified as root causes of weak science learning outcomes. The STEs' recognition that "education and economy cannot be separated" underscores the interdependence between science education reform and national development (OECD, 2018, 2023).

Taken together, the findings suggest that the challenges facing science education in Indonesia arise not from a single factor but from systemic misalignment among policy, practice, and socioeconomic conditions. Three key implications emerge. First, national standardization and accreditation systems are needed to ensure more equitable quality across teacher education institutions. Second, policies promoting inquiry-based science learning must be supported by sustained investment in laboratory infrastructure, teacher welfare, and continuous professional development. Third, education reform must be participatory and context-sensitive, involving collaboration among policymakers, universities, and schools. Overall, improving science education in Indonesia requires systemic reform that addresses multiple levels of the education system simultaneously, including policy, institutions, and classroom practice, as education reform is most effective when implemented in a coherent and integrated manner across these levels (Darling-Hammond & Lieberman, 2013).

CONCLUSION AND RECOMMENDATION

Conclusion

This study explored STEs' perceptions of the quality of science education in Indonesia and the systemic factors influencing it. The results indicate that STEs regard challenges in science education as systemic, characterized by disparities in the quality of teacher preparation, ineffective inquiry-based learning methodologies, structural and economic limitations, policy volatility, and cultural impediments. These findings indicate that science education problems in Indonesia are not caused by individual teachers alone but by systemic misalignment between teacher education, school practice, and education policy. The study also indicates that STEs see themselves as agents of change who can improve science education through teacher preparation, mentoring, and professional collaboration. Therefore, improving science education in Indonesia requires strengthening teacher education institutions, improving teacher welfare, ensuring policy consistency, and supporting inquiry-based science learning.

Recommendation

To enhance the quality of science education in Indonesia, coherent and sustained reforms are required to align teacher preparation, school practice, and policy direction. Strengthening national accreditation and quality assurance systems would help reduce disparities in teacher competence and institutional performance. Policies promoting inquiry-based science learning should be supported by adequate laboratory facilities, professional development opportunities, and improvements in teacher welfare to sustain motivation and innovation.

Equally important is fostering a reflective, collaborative professional culture among STEs, enabling them to act as agents of change that bridge the gap between policy expectations and classroom realities. Sustainable progress will depend on consistent coordination between universities, schools, and government bodies to ensure that reform efforts are contextually grounded, inclusive, and evidence-based.

A limitation of this study is that it examined only the perspectives of STEs. Recommendations for future research should include science teachers as participants to gain a more comprehensive understanding of the challenges faced in actual classroom practice. Including teachers' perspectives would allow researchers to compare university-based teacher education perspectives with school-based teaching realities, thereby providing a more in-depth understanding of the alignment between teacher preparation and classroom practice.

Use of Generative AI tools declaration

AI writing assistance (Grammarly Premium) was used solely for language and structural editing. All research ideas, analyses, and interpretations were developed by the authors. The manuscript was carefully reviewed and revised by the authors, who take full responsibility for its content.

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