The role of human resources in enhancing scientific literacy to improve the quality of education for Indonesia's Golden Year 2045.

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ARTICLE INFO	ABSTRACT
	Strengthening human resources (HR) is essential to improve education quality and realize Indonesia's Golden Year 2045. Low scientific and digital literacy among students, uneven teacher preparedness, and traditional curricula hinder the nation's capacity to innovate. This study used a qualitative approach conducted from March 4 to April 20, 2023, in two junior high schools in Tangerang Regency. Data were collected through purposive semi-structured interviews with principals, science teachers, and students, and document analysis of curricula, lesson plans, assessments,. Data were thematically analyzed with triangulation, peer debriefing, and member checking to ensure trustworthiness. Findings reveal that HR—teachers, school leaders, policymakers, higher education, and students—play pivotal roles in enhancing scientific literacy. Effective professional development, leadership support for inquiry-based , accessible digital learning resources, and student engagement in research activities significantly improved scientific reasoning, experimentation, and innovation mindsets. Conversely, weak HR systems and theoretical pre-service training limited classroom translation of competencies. The study concludes that coordinated investment in teacher capacity, curriculum reform toward outcome-based and STEM-integrated training, student-centered research opportunities, and governance incentives are necessary to raise scientific literacy

INTRODUCTION

Strengthening the quality of human resources (HR) is a primary prerequisite in efforts to improve the quality of education toward the vision of Golden Indonesia 2045. The era of globalization and technological development requires the younger generation not only to master knowledge but also to possess critical thinking skills, the ability to innovate, and strong scientific literacy so they can compete nationally and internationally. Scientific literacy is a strategic component because this ability not only reflects mastery of scientific concepts but also the capacity to apply that knowledge in real life, solve problems, and make evidence-based decisions. Various studies show that improving scientific literacy directly contributes to the effectiveness of the learning process and the readiness of students to face future challenges (Lendeon & Poluakan, 2022; Kimianti & Prasetyo, 2019).

Current conditions indicate weaknesses in learning skills, mastery of media, and information among students, which lead to less effective learning processes (Lendeon & Poluakan, 2022). Low scientific literacy limits students' ability to understand natural phenomena, use scientific methods, and innovate. If not addressed, this condition will hinder the formation of quality human resources needed to realize the 2045 vision. Therefore, systematic efforts to improve scientific literacy through curriculum, teaching strategies, and development of learning resources are essential. Twenty-first century education transformation emphasizes the development of 21st Century Skills—such as critical thinking, collaboration, creativity, and digital literacy—which align with the goal of producing a superior, intelligent, competitive, and character-driven generation (Puspa, 2023).

The implementation of appropriate learning models has been shown to improve scientific literacy. Problem-Based Learning (PBL), for example, has been studied in various educational contexts and shown positive results. Herman et al. (2022) found an increase in scientific literacy learning outcomes among Class VIIIA students after implementing the PBL model, indicating that problem-based approaches can enhance students' conceptual understanding and scientific application. Similarly, trials using problem-based learning models for prospective chemistry teachers showed increased scientific literacy after instruction (Bahriah, 2015). Other results from PBL implementation also support that differentiated, problem-based instruction can improve students' scientific literacy, as reported by Tilamsari et al. (2023), who observed an increase in average scores after PBL implementation. These findings reinforce the argument that PBL, as an active learning model, can stimulate student engagement in the learning process, improve problem-solving skills, and encourage transfer of knowledge to real-life contexts.

The development of digital learning resources, such as PBL-based e-modules, also offers practical and contextual solutions to support scientific literacy. Kimianti & Prasetyo (2019) showed that a PBL-based science e-module can serve as an alternative learning resource that is accessible, relevant, and practical, supporting flexible and contextual learning processes. Utilizing digital media is important considering the challenges of limited technology and information mastery among students; well-designed digital learning resources can simultaneously enhance scientific literacy and digital literacy.

At the macro level, developing competent human resources is not only the responsibility of formal education but requires synergy among stakeholders: government, educational institutions, industry, and society. Sudarma (2022) emphasizes that future human resources must be acceptable and able to compete alongside the global workforce; character education is seen as crucial in preparing the Golden Generation of 2045 with competitive capabilities. Character education combined with scientific literacy will form individuals who are not only intellectually competent but also responsible, ethical, and adaptive to change. Thus, programs to enhance scientific literacy need to integrate aspects of character, scientific ethics, and educational policies that support pedagogical innovation.

Moreover, twenty-first century education transformation requires curricula and assessment methods to be adapted to better evaluate scientific process skills, higher-order thinking abilities, and collaboration, rather than relying solely on rote tests (Puspa, 2023). Evaluation and monitoring of learning quality should measure scientific literacy progress authentically through portfolios, problem-based projects, and performance assessments. Such approaches will encourage students to internalize scientific knowledge in real contexts while building competencies relevant to industry and society's future needs.

Overall, the role of human resources in improving scientific literacy is decisive in efforts to raise educational quality toward Golden Indonesia 2045. Enhancing scientific literacy must be pursued through strengthening effective learning models like PBL, developing contextual digital learning resources, improving teacher capacity, and implementing educational policies that support the development of 21st Century Skills and character education. With these integrated steps, future generations are expected to have scientific competence, global competitiveness, and strong character to realize the nation's vision by 2045.

METHOD

This study employed a qualitative research approach to explore the role of human resources in enhancing scientific literacy and improving education quality. The research was conducted from 03/04/2023 to 04/20/2023 in two junior high schools (SMP) in Tangerang Regency. Data collection prioritized in-depth understanding of participants' perspectives and institutional practices, using semi-structured interviews and document analysis as primary instruments. Purposive sampling was used to select key informants, including science teachers, school principals, and selected students who were directly involved in or affected by literacy initiatives, ensuring diverse viewpoints relevant to the phenomenon under study. The fieldwork began with preliminary visits to obtain access and contextual orientation, followed by scheduling and conducting face-to-face interviews focused on participants' experiences with teaching methods, professional development, resource availability, and perceived outcomes on scientific literacy. Interviews were audio-recorded with consent and supplemented by observational notes to capture

nonverbal cues and contextual details. Documentation review encompassed curriculum materials, lesson plans, assessment records, school improvement plans, and any existing e-modules or PBL resources to triangulate evidence and trace institutional support for literacy practices.

Data analysis followed an iterative thematic approach: transcribing interview recordings, coding transcripts and documents, and grouping codes into categories that reflected emerging patterns and meanings. Constant comparison across cases enabled identification of similarities and differences between the two schools. Reflexive memos were maintained throughout to record analytic insights and researcher positioning. Trustworthiness was ensured through triangulation of data sources (interviews and documents), investigator triangulation through peer debriefing, and member checking by sharing preliminary findings with selected informants for validation. Ethical considerations, including informed consent, confidentiality, and secure data storage, were observed. The study concluded by synthesizing themes that illuminated how human resource capacities, pedagogical practices, and institutional supports interact to influence students' scientific literacy and overall education quality.

RESULT AND DISCUSSION

The findings of this study underscore the central role of human resources (HR) in enhancing scientific literacy as a foundational pathway toward improving the quality of education in pursuit of Indonesia's Golden Year 2045. Educators, school leaders, policymakers, and students together comprise a dynamic human capital ecosystem whose capacities, dispositions, and actions determine how well scientific knowledge is internalized, applied, and extended into innovation. First, HR function as the principal drivers of educational transformation. Teachers and education policymakers emerge as "game changers" who translate national strategies into classroom realities. Policy initiatives such as accelerating compulsory education to thirteen years and restructuring teacher management to produce STEM-ready graduates provide a framework, but their impact depends heavily on HR capability to operationalize reforms. In the two junior high schools studied, proactive school leaders aligned professional development with national STEM priorities, enabling teachers to adopt inquiry-based pedagogies and to integrate problem-based learning (PBL) resources. Where administrators prioritized continuous teacher training, coaching, and collaborative lesson planning, classrooms demonstrated higher levels of student engagement in scientific reasoning and experimentation. Conversely, schools with weak HR systems—limited mentoring, irregular professional learning, and constrained autonomy—showed slower uptake of innovative pedagogies, illustrating how HR capacity mediates policy effects.

Second, HR act as essential agents bridging the literacy gap that currently constrains Indonesia's competitiveness. Low levels of digital and scientific literacy among students reflect both resource inequities and inconsistent teacher preparedness. The study found that targeted HR interventions—structured in-service training on science pedagogy, digital tool fluency workshops, and peer learning communities—substantially improved teachers' confidence and practices. Teachers who received hands-on training with e-modules and classroom technologies designed to scaffold scientific inquiry reported more frequent use of authentic assessments and integration of real-world problem contexts. This shift enabled students not only to consume scientific information but to evaluate, synthesize, and produce knowledge. Importantly, HR development focused on cultivating teacher mindsets that regard students as knowledge producers rather than passive recipients; such cultural changes are pivotal for moving the nation from being a market for innovation to a source of innovation.

Third, higher education and pre-service training institutions as HR producers must adapt curricula to meet global STEM and skills standards. Findings indicate that when teacher education programs incorporate practical STEM pedagogy, digital literacy, and outcome-based education (OBE) principles, novice teachers enter schools better prepared to foster scientific literacy. Several participants reported that graduates from programs emphasizing laboratory skills, interdisciplinary projects, and teaching practicums using PBL strategies were more adept at designing student-centered lessons and assessments aligned to competencies rather than rote memorization. The integration of OBE reorients curriculum design toward

demonstrable competencies—critical thinking, experimental design, data interpretation, and scientific communication—thereby enabling HR at all levels to produce graduates who can teach and model these competencies. Where higher education remained predominantly theoretical, schools struggled to translate content knowledge into classroom practices that cultivate scientific literacy.

Fourth, students themselves are a critical dimension of HR, deserving of investment as agents of change. The research shows that when education systems treat students as active contributors to knowledge creation—through involvement in research projects, school-based R&D, science clubs, and community problem-solving initiatives—student motivation and scientific literacy improve markedly. In the observed schools, student-led mini-research projects supported by teacher mentors fostered skills in hypothesis formulation, data collection, analysis, and dissemination. These activities also promoted collaborative skills and an innovation mindset. Empowering students with opportunities to participate in local research initiatives connected classroom learning to societal challenges, reinforcing the relevance of science and building a pipeline of young innovators ready to contribute to technological and social advancement.

Finally, effective HR systems require governance structures and incentives that sustain continuous improvement. The study found that performance management systems linking teacher appraisal to professional growth, incentives for innovation in pedagogy, and accountability mechanisms were associated with better outcomes in scientific literacy. Cross-sector partnerships—between schools, universities, industry, and local government—enhanced resource availability and provided authentic contexts for STEM application. Moreover, digital platforms for sharing best practices and open educational resources amplified the reach of successful interventions, particularly where geographic disparities exist.

Coclusion

Human resources are the linchpin for advancing scientific literacy and elevating education quality toward the 2045 goal. Transformative policy directions must be matched with investments in teacher development, curriculum reform in higher education, student empowerment through research engagement, and systemic governance that rewards continuous professional learning and pedagogical innovation. When HR across the education ecosystem are capacitated, coordinated, and incentivized to prioritize scientific inquiry, problem solving, and digital fluency, the resulting gains in scientific literacy will strengthen national capacity to innovate and compete globally, moving Indonesia closer to its Golden Year ambitions.

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