

## PROBLEMATICS OF SCIENCE EDUCATION: HUMAN RESOURCES, TEACHERS AND PROSPECTIVE TEACHERS

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**Abstract:** This study explores how important educational resources and infrastructure are to raising the calibre and efficacy of science instruction. It highlights how crucial physical resources like laboratories and learning tools, as well as digital media like eBooks and instructional videos, are to creating a vibrant and engaging learning environment. Notwithstanding the possible advantages, the research points to several important obstacles, such as insufficient funding, a lack of standardized equipment, restricted resource availability, and a lack of teacher preparation in technology integration. To address these issues, a thorough strategy is suggested, emphasizing continual professional development for teachers and matching curriculum requirements with available resources. The results show that to guarantee fair access to educational resources and enhance the results of science education, stakeholders must work together and have strong policy support.

**Keywords:** Science Education; Educational Infrastructure; Digital Media; Teacher Training; Equity in Education

### 1. INTRODUCTION

A vital component of the educational system, science teachers' human resources (HR) are entrusted with developing a future generation that is scientifically literate, capable of critical thought, and has a profound awareness of the natural world (Suparya et al., 2022). Beyond merely imparting knowledge, science teachers have a strategic and multidimensional role that includes helping students develop their scientific skills, fostering positive scientific attitudes, and turning difficult scientific concepts into approachable learning experiences. Science teachers accompany students on their quest to investigate, challenge, and comprehend natural phenomena and the ever-evolving body of scientific knowledge in the classroom. They are not only educators but also intellectual mentors, motivators, and inspirers. In fostering curiosity, promoting inquiry-based learning, and equipping students to actively engage with scientific challenges in a world that is changing quickly, their role is essential.

A thorough set of competencies that include both content knowledge and pedagogical expertise determines the credentials of a qualified science teacher or aspiring teacher. First and foremost, to guarantee the accurate and significant presentation of subject matter, a thorough understanding of scientific concepts, theories, and principles is necessary. The pedagogical capacity

to successfully impart this knowledge in ways that are interesting and accessible to a wide range of learners is equally crucial. Since practical experimentation is a fundamental component of science education, promoting inquiry skills and strengthening theoretical understanding, proficiency in planning and carrying out laboratory practicums is also essential (Hasan, 2018). Additionally, it is expected of science teachers to be creative and innovative in creating educational materials and teaching strategies that pique students' interest and encourage active learning. Beyond technical proficiency, a science teacher needs to have a scientific mindset that is marked by a high degree of objectivity, honesty, curiosity, and openness to new concepts and scientific discoveries. These qualities are essential for both setting an example of scientific thinking for students and for continuously adjusting to the changing landscape of scientific knowledge and teaching methods.

Despite the importance of these competencies, the development of science teacher human resources faces several systemic challenges. A key issue is the persistent disconnect between teacher education curricula and the actual demands of the classroom. This misalignment often results in new teachers being inadequately prepared for the practical realities of their profession. Moreover, the limited availability of continuous professional development programs restricts teachers' ability to stay current with advances in science and pedagogy or to adopt innovative instructional practices. These problems are further compounded by disparities in access to modern educational resources and technology, particularly in under-resourced and remote regions.

To overcome these challenges, a comprehensive and integrated approach to science teacher development is essential. Such an approach must span the entire professional continuum—from recruitment and pre-service education to ongoing in-service training and professional mentoring. This includes establishing relevant, practice-oriented teacher preparation programs, ensuring equitable access to professional learning resources, and fostering a culture of continuous improvement. Strengthening collaboration among government bodies, teacher training institutions, educators, and other key stakeholders is also critical to building a sustainable and effective science teaching workforce.

Investing in the human resources of science teachers is fundamental to achieving high-quality science education. A well-supported teaching force not only delivers curriculum content effectively but also inspires students to think critically, act creatively, and engage with scientific challenges. By strengthening the ecosystem that supports science teacher development, we can better prepare future generations to navigate and address the complex global issues of the twenty-first century with resilience, innovation, and scientific integrity.

## 2. RESEARCH METHODS

To identify current research trends regarding the human resource capabilities of science teachers and aspiring teachers, this study uses a literature review method. The review focuses on competency development, digital literacy, and pedagogical skills in the context of modern learning environments. To guarantee the inclusion of reliable and pertinent sources, a thorough and methodical search was carried out across a few respectable scientific journal databases.

Predetermined inclusion and exclusion criteria were used to direct the selection process. If a study was published within a certain time the last 10 years and addressed teacher or prospective teacher competencies in the areas of pedagogy, professional development, or digital literacy, it was included. Articles that lacked theoretical or empirical rigor or failed to satisfy the relevance requirements were disqualified.

The information gathered from the literature was methodically synthesized after the selection process. Finding important themes, emphasizing current research gaps, and developing a theoretical framework that can guide further empirical studies were the main goals of the synthesis. The results are guaranteed to be based on a careful and critical analysis of the body of existing knowledge thanks to this methodological approach.

## 3. RESULTS AND DISCUSSIONS

### A. The Role of Pedagogy in Teacher Professional Development

Pedagogy represents a fundamental pillar in the development of teacher professionalism. A teacher's pedagogical competence is crucial, as it directly influences the design, implementation, and evaluation of curriculum and learning processes within the classroom. Mastery of pedagogical skills enables teachers to effectively plan instruction, facilitate meaningful learning experiences, and adapt teaching strategies to meet diverse student needs. Understanding the current state of teachers' pedagogical competencies is essential not only for improving instructional quality but also as a foundation for further research into related areas of professional capability. Specifically, insights into pedagogical competence can inform the exploration of other critical dimensions of teacher professionalism, including personal competence, social competence, and professional competence (Mayasari et al., 2023). By strengthening pedagogical foundations, educators can be better prepared to foster holistic student development and respond to the evolving demands of the education system.

Teachers must have a thorough understanding of both the theory and practice of effective

learning because they are essential human resources in the educational process. This includes the capacity to develop and execute curricula that are pertinent and responsive to the demands of modern education, establish welcoming and encouraging learning environments, and use a range of teaching techniques catered to the various needs and traits of students (Pursitasari et al., 2023; Vilmala et al., 2022). By improving their pedagogical competence, educators can not only maximize the teaching and learning process but also play the role of facilitators, inspiring, motivating, and empowering students to realize their greatest potential (Alimuddin et al., 2023). Teachers must receive ongoing professional training and development to stay flexible, creative, and able to provide high-quality instruction that is in line with present and future demands, given the quick changes in educational paradigms and societal demands.

It is becoming more and more important to prepare aspiring educators to meet the demands of modern education, especially considering the quick changes in technology and changing teaching strategies. Strong digital competencies, such as the capacity to successfully incorporate a variety of technological tools into the teaching and learning process, are essential for future educators to develop (Priyambodo and Saputri, 2021). This entails organizing, presenting, and delivering learning materials in ways that improve student engagement and comprehension through technology, in addition to becoming proficient in the technical aspects of using digital platforms. Additionally, aspiring educators need to be prepared to design technologically advanced, collaborative, interactive, and student-centred learning environments (M. Mustika and Temarwut, 2022). Teachers must modify their teaching methods to accommodate the preferences, expectations, and learning styles of today's students, who are digital natives' people who are naturally accustomed to technology and information systems. To prepare teachers who can succeed in increasingly technologically advanced educational environments, it is imperative that teacher education programs incorporate digital literacy and adaptive pedagogical skills.

To accomplish these objectives, aspiring educators are urged to actively participate in ongoing education and adjust to new developments in the field, especially by attending workshops, seminars, and training courses centered around educational technology. Future teachers must develop the capacity to encourage active student collaboration and encourage critical thinking to solve real-world issues, in addition to technical proficiency. In addition to being better prepared to handle the ever-changing demands of modern education, aspiring educators who cultivate these competencies will also be able to act as role models for students, encouraging them to become lifelong learners who can thrive in a constantly shifting global environment (Mardhiya and Zahra,

2022).

### **B. Methods for Increasing Pedagogical Proficiency**

Using a variety of focused tactics is necessary to increase teachers' pedagogical proficiency. Specialized training programs and workshops that emphasize improving essential teaching abilities, incorporating technology into the learning process, and using creative approaches to address individual differences in the classroom are one successful strategy (Wahyuni and Haryanti, 2024). In addition to helping teachers improve their teaching methods, these professional development opportunities keep them up to date on the most recent developments in pedagogy. Furthermore, encouraging teacher collaboration through peer mentoring, discussion groups, or learning communities can be a potent tool for professional development and knowledge exchange (Mustika et al., 2024). In the end, these collaborative spaces enhance educators' pedagogical perspectives and promote innovative problem-solving by enabling them to share best practices, discuss ideas, and work together to address shared challenges. Teachers who improve their pedagogical competence in these ways are better equipped to deliver high-quality instruction and are also more confident as professionals, prepared to handle the changing demands and complexities of the contemporary educational environment (Satar et al., 2025).

### **C. Increasing the Professionalism of Teachers**

Enhancing teacher professionalism requires self-improvement and ongoing learning (Supit et al., 2021). Teachers can stay up to date on the most recent advancements in educational theory, pedagogical practices, and technological innovations through seminars and well-aimed training programs (Efendi and Sholeh, 2023). These professional development activities encourage teachers to share their knowledge, experiences, and best practices with their peers, while also offering useful updates on current trends in education (Bramastia et al., 2023). For example, planning training sessions that emphasize cutting-edge teaching techniques can enable educators to embrace more successful, student-centered strategies, which raises the standard of instruction in the classroom. Additionally, receiving formal certifications from accredited training programs inspires teachers and increases their professional confidence and dedication to their work in addition to validating their competencies (AD et al., 2023). Teachers are better equipped to handle the changing demands of contemporary education and help to improve educational outcomes overall by incorporating such ongoing professional development initiatives. The use of Classroom Action Research (PTK) techniques is a successful tactic for raising teacher professionalism in addition to formal training (Wardani et al., 2019). By allowing teachers to methodically examine and consider their own

teaching methods, PTK promotes ongoing enhancements grounded in empirical research. Teachers become more cognizant of the various needs of their students and the dynamics of learning when they take on the role of researchers in their own classrooms. In addition to improving teachers' pedagogical abilities, this reflective approach promotes increased autonomy, professional confidence, and a proactive approach to resolving issues in the classroom (Annury, 2019). To develop teachers who are not only proficient in their field but also flexible and sensitive to the constantly changing needs of the educational system, it is essential to combine structured professional development programs with reflective practices like PTK. An integrated approach like this helps teachers become reflective practitioners who can advance their own careers and help improve educational outcomes more broadly.

#### **D. Enhancing Teacher Professionalism through Innovation Learning**

To improve teacher professionalism and the general standard of education, innovation in learning is essential. Educational innovation is the introduction and use of new approaches, technologies, and teaching methods with the goal of increasing student engagement, fostering deeper understanding, and improving the effectiveness of learning (Rahmawati and Nurachadija, 2023). The incorporation of digital technologies, such as educational apps, online learning platforms, and collaborative tools, is frequently a key innovation. These tools allow students to learn independently while facilitating interaction with peers, teachers, and outside resources (Achyandia, 2023). In addition to making education more accessible, these technological developments also produce dynamic, interactive learning environments that inspire students to take more charge of their education. Adopting these innovations helps educators create more flexible, interesting, and successful teaching strategies, which eventually improves their professionalism. Teachers who incorporate these new approaches into their lessons not only enhance the quality of their instruction but also help create a more inclusive, student-centered, and participatory learning environment.

In addition to technological advancements, innovations in education also encompass the development of curricula that are more closely aligned with the needs of the real world. One such innovation is project-based learning, which allows teachers to facilitate collaborative group discussions, provide continuous feedback, and guide students through the process of inquiry and problem-solving (Gusti et al., 2020). This approach not only fosters teamwork and communication skills but also enables students to engage in meaningful, hands-on learning experiences. Another significant innovation is the adoption of interdisciplinary approaches that integrate knowledge and methodologies from various disciplines, encouraging students to draw connections across fields of

study (Rahim, 2024). This approach helps students cultivate the critical thinking, creativity, and problem-solving abilities essential for addressing the complex, multifaceted challenges they will encounter in the future. By combining these innovative pedagogical strategies with the use of advanced technology, education can become more engaging, inclusive, and effective in preparing students for an increasingly dynamic and interconnected world. The integration of such innovations fosters a learning environment that is not only more responsive to the diverse needs of students but also better equipped to address the evolving demands of 21st-century education, thereby enriching students' overall learning experiences.

### **E. Human Resource Development (HRD) for Teachers and Teacher Candidates**

#### **1. Core Competencies in Teacher Development**

Human resource development for science educators' centers on four essential competencies: pedagogical, professional, social, and personal. Pedagogical competence involves designing effective, student-centered learning, managing classrooms, and implementing relevant assessments. Teachers must also adapt curricula, apply learning technologies, and accommodate diverse learning needs to support student growth holistically (Lestari and Kurnia, 2023; Muhsim et al., 2023; Nursalim et al., 2024).

#### **2. Strengthening Professional and Social Skills**

Professional competence includes mastery of subject matter, research capabilities, and the ability to innovate instructional strategies. Ongoing professional development, such as conferences, research, and IT integration, is crucial. Social competence focuses on communication, empathy, collaboration, and conflict resolution skills vital for building positive relationships with students, peers, and the wider school community (Akhyar et al., 2024; Iskandar et al., 2023).

#### **3. Personality and Managerial Competence**

Personality traits such as integrity, discipline, creativity, and emotional resilience shape teacher professionalism and role modelling. Meanwhile, managerial competence includes planning, organizing, classroom management, and problem-solving. Together, these skills enable teachers to lead structured, adaptive, and student-friendly learning environments (Judijanto et al., 2025; Naibaho and Manalu, 2024).

#### **4. Strategies and Impact of Continuous Development**

Effective teacher development requires structured approaches such as training, mentoring, advanced studies, and performance evaluation. These strategies enhance teachers' capabilities

and contribute to inclusive, engaging education. Investing in teacher development not only improves learning outcomes and student engagement but also builds a resilient, future-ready education workforce (Widyanto et al., 2023; Wijaya, 2023).

#### **F. The Value of Digital Literacy Skills for Future Teachers in the Twenty-First Century**

Digital literacy has emerged as a crucial pillar for promoting creativity, innovation, and entrepreneurship in today's increasingly digital world. Digital literacy gives people the tools they need to successfully navigate the complexity of the digital world and participate meaningfully in contemporary society as the demands of the twenty-first century change. Because it directly affects their capacity to adjust to new learning environments and technological advancements, this study highlights the vital importance of digital literacy, especially for educators and students. People may find it difficult to keep up with the quick changes in technology and may not acquire the skills needed to prosper in a technologically advanced society if they lack adequate digital literacy.

This problem is even more urgent for educators. In addition to being experts in their subjects, educators also need to be skilled at converting that knowledge into interesting, interactive, and easily accessible digital formats (Fahkiroh et al., 2023). Teachers must use digital tools and platforms to improve learning, encourage student engagement, and accommodate a variety of learning styles because relying solely on traditional teaching methods is no longer adequate in the twenty-first century. Additionally, educators need to be skilled in digital pedagogy so they can use technology to promote problem-solving, collaboration, and critical thinking. Therefore, it is crucial for aspiring educators to acquire digital literacy skills to advance professionally and to better prepare students for success in a world that is becoming more digitally connected.

The continuous transition from conventional classroom settings to virtual learning environments is indicative of how education is changing more broadly in response to technological breakthroughs. The study's conclusions show that while aspiring educators have a firm grasp of digital literacy principles, they still need to improve how they apply these principles in practice. In particular, the use of digital tools like social media, websites, and online games as useful learning resources needs to be improved. Even though aspiring educators may understand the theoretical underpinnings of digital literacy, it can still be difficult to translate this understanding into useful, interesting, and pedagogically sound applications. Thus, it is essential that efforts to improve students' and teachers' digital literacy remain a continuous process. These initiatives are crucial to guaranteeing that the following generation has the skills required to prosper in a world that is



becoming more technologically advanced and interconnected, as well as the readiness to meet the challenges of the digital age (Naila et al., 2021).

In the current world, where information technology is advancing at a rapid pace, digital literacy has become essential. Digital content access, analysis, evaluation, and creation skills are now essential for success in the workplace, in the classroom, and in personal life. As learning facilitators, educators are essential to helping students become digitally literate. By incorporating digital technologies into the classroom, teachers not only impart academic knowledge but also equip students with the skills necessary for responsible and informed digital citizenship by teaching them how to successfully navigate the digital world.

Social media sites, for example, can be useful resources for fostering student cooperation, facilitating conversations, and advancing information exchange. When used carefully, these platforms can offer a variety of learning opportunities and improve student engagement. But it's important to understand that digital literacy goes beyond just knowing how to use digital tools. It also includes the improvement of communication, problem-solving, and critical thinking abilities in a digital setting. Therefore, the emphasis of teaching digital literacy needs to change from merely learning how to use digital tools to developing the capacity to think critically and morally in online settings. Continuous efforts are required to help educators and students develop their theoretical knowledge and practical digital skills to accomplish this (Sianipar et al., 2023). Teachers can guarantee that students have the abilities needed to succeed in a world that is becoming more digital and complex by maintaining the emphasis on digital literacy.

### **G. The Connection Between Students' ICT Proficiency and Teachers' Using Digital Literacy to Address Science Learning Obstacles**

Knowledge of information and communication technology (ICT) has become crucial for educators in today's increasingly sophisticated digital age. To improve the quality of their teaching methods and successfully engage students, teachers must now be proficient in ICT in addition to being in charge of imparting subject matter (Handiyani and Abidin, 2023). Teachers can design dynamic, interactive, and customized learning experiences that appeal to students' digital needs and preferences by incorporating technology into the teaching and learning process. Digital simulations, collaborative online platforms, and interactive multimedia are just a few of the new teaching methods made possible by technology that can help students in the digital age find learning more interesting and relevant (Sari and Alfijan, 2023).

Furthermore, developing teachers' ICT proficiency is essential to fostering students' digital

literacy, which includes abilities like finding, assessing, and applying information from a variety of digital sources. In addition to enabling students to successfully navigate the vast digital landscape, a solid foundation in digital literacy aids in the development of 21st-century critical thinking and problem-solving abilities. According to research, students' academic achievement and levels of digital literacy are significantly positively correlated with teachers' ICT proficiency (Judijanto, 2024). Teachers who become proficient in ICT also help their students acquire these critical skills, creating an atmosphere that supports self-directed learning, online collaboration, and well-informed decision-making. To improve the quality of education and make sure that it stays relevant and responsive to the demands and challenges of the digital age, it is imperative that ongoing investments be made in teachers' ICT competencies.

Teachers' roles as learning facilitators have grown more complicated in the rapidly changing digital landscape. Teachers are now expected to use information and communication technology (ICT) to enhance the learning process and design educational experiences that meet the needs of today's tech-savvy students, in addition to being subject matter experts. In addition to helping teachers deliver more dynamic, interesting, and pertinent lessons, teachers' ICT proficiency is essential for improving students' digital literacy (Kurniawan and Sarah, 2023). By incorporating digital tools into the classroom, educators can provide cutting-edge teaching strategies like collaborative tools, virtual labs, and real-time feedback systems, all of which enhance the dynamic learning environment.

For students to thrive in the contemporary, connected world, they must possess digital literacy, which includes abilities like finding, analysing, and applying information from various digital sources (Ariastika, 2022). Students with this competency can evaluate digital information critically and make effective use of it for both academic and personal growth. Numerous studies have confirmed that there is a positive relationship between teachers' ICT skills and student learning outcomes. Effective, technology-enhanced learning experiences are more likely to be created by teachers with strong ICT skills, and this helps students achieve better academically. These results make it abundantly evident that investing in teachers' ongoing ICT competency development is essential to guaranteeing the provision of high-quality instruction that equips students for the demands of the digital age (Cynthia and Sihotang, 2023).

## 4. CONCLUSIONS AND SUGGESTIONS

### CONCLUSIONS

Optimizing science education infrastructure and integrating appropriate technology are essential to improving students' science literacy and critical thinking skills. However, resource constraints and implementation gaps are major barriers, requiring a systemic approach that includes advocacy policies, strategic resource allocation, and comprehensive teacher training. Investment in infrastructure and collaboration between institutions are also needed to create a science education system that is more efficient, equitable, and ready to face future challenges.

### SUGGESTIONS

Prioritize research on the long-term impact of educational resources and technologies on student engagement and learning outcomes, Develop and evaluate teacher training programs to improve technology literacy and effective learning integration, Implementation of pilot projects in underserved communities is also important to ensure equitable access to standardized science learning tools and resources, Policy support that provides sustainable funding and encourages collaboration among educational institutions is essential, and the development of community science centers and the implementation of inclusive strategies should be promoted to make quality science education more accessible to all, especially marginalized groups.

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