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# Teachers Knowledge and Skills in Using AI in Science Subjects: A Systematic Literature Review

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**Abstract**

Artificial intelligence (AI) is increasingly being integrated into education, including science teaching, creating a growing need for teachers to possess appropriate knowledge and skills to use the technology effectively. This systematic literature review aimed to identify the level of teachers' knowledge and skills regarding the use of AI in Science subjects. The review was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A total of 1,456 articles were initially identified from Scopus, Web of science, and Google Scholar. Following the screening, eligibility, and quality assessment processes using the Mixed Methods Appraisal Tool (MMAT), 34 articles published between 2022 and 2026 were included in the final analysis. The findings indicate that teachers' knowledge regarding the use of AI in science teaching is generally at a basic and developing level, particularly in relation to pedagogical applications, technological limitations, evaluation of AI-generated content, and appropriate use in science teaching. Teachers also demonstrate limited skills in using AI, particularly in technical application, pedagogical integration, assessment and scientific modelling, adaptation to students' learning needs, and responsible use. The findings further highlight the importance of structured and continuous professional development, technology-related experience, accessible training resources, and opportunities for practical application in supporting the development of teachers' AI knowledge and skills. Overall, meaningful AI integration in science teaching requires the development of both teachers' knowledge and practical skills, supported by professional learning that integrates technological, pedagogical, and science-content knowledge.

**Keywords:** Artificial Intelligence (Ai), Science Teachers, Skills, Knowledge, Science Teaching

## Introduction

The rapid development of Artificial Intelligence (AI) technology has led to significant transformations in education, particularly in the teaching and learning of science. According to Dahliyah (2024), AI has the potential to enhance teachers' efficiency, personalise students' learning, and facilitate automated formative assessment. The use of AI tools such as ChatGPT, intelligent tutoring systems, and adaptive applications has been reported to support students in understanding abstract concepts more effectively (Almasri 2024).

However, the effectiveness of AI integration in science teaching depends on the level of teachers' knowledge and skills in using the technology (Aminah & Crispina 2024). Studies have found that novice teachers are more likely to master new technologies compared to

experienced teachers, who often face constraints such as concerns about technology usability and limited exposure to AI (Okunade 2024). This highlights the importance of teachers' technological pedagogical knowledge in supporting the effective integration of AI into science teaching.

Furthermore, the Digital Education Policy (DPD), introduced by the Ministry of Education Malaysia (MOE) in 2023, emphasises the need for teachers' professional development to enable them to effectively integrate technologies such as AI into teaching. This policy serves as a key pillar in ensuring that teachers are equipped with digital skills in line with the Industrial Revolution 5.0.

In addition to the pedagogical aspect, the use of artificial intelligence (AI) in science teaching is also closely related to the need for the transformation of the 21st-century education curriculum. The science curriculum emphasises the development of higher-order thinking skills (HOTS), problem-solving, digital literacy, and inquiry-based learning, which are relevant to the integration of AI in teaching and learning. The integration of AI in science teaching may also support STEM-oriented learning through more interactive, adaptive, and student-centred approaches.

However, studies have shown that many teachers face challenges related to training, access to resources, and time constraints in learning and applying AI in science teaching (Li et al. 2026). According to the study by Cheung et al. (2024), the level of technological literacy and the suitability of technology for teaching tasks greatly influence teaching effectiveness. Therefore, it is important to identify the extent of teachers' knowledge and skills in using AI in the context of teaching, particularly science teaching.

Although there has been an increase in the number of studies related to the use of artificial intelligence (AI) in education, most studies focus more on the perceptions, acceptance, and potential of AI in teaching in general. Studies that specifically examine science teachers' knowledge and skills regarding the use of AI remain limited. In addition, findings from previous studies remain fragmented and have not been systematically synthesised to identify patterns, challenges, and teachers' professional development needs comprehensively. Therefore, this systematic literature review was conducted to address this gap by synthesising the latest empirical evidence related to teachers' knowledge and skills in the use of AI for science teaching.

*Research Problem*

The development of artificial intelligence (AI) technology in the education sector has opened up new opportunities for innovation in teaching and learning. AI is seen as capable of supporting a more adaptive and student-centred learning process (Almalki et al. 2022). However, various studies have shown that teachers' level of knowledge regarding AI applications in education remains low, particularly among science teachers (Zainuddin et al. 2023). A lack of technological literacy and understanding of basic AI concepts causes teachers to face challenges in identifying the true potential of this technology to effectively enhance science pedagogy (Chong et al. 2023).

In terms of skills, many teachers do not possess sufficient technical competencies in using AI applications or software that are appropriate for the classroom context (Lee et al. 2024). This is due to the lack of specialised training focusing on the use of AI in education as well as the absence of adequate support resources at the school level (Rahim & Kamaruddin 2021). In addition, teachers' professional development has yet to systematically emphasise the integration of AI into the curriculum, particularly in science teaching, which requires an inquiry-based approach (Noraini et al. 2023). Furthermore, teachers still have limited exposure to clear curriculum guidelines related to the use of AI in science teaching. This situation causes the use of AI to be more focused on individual teachers' initiatives rather than being part of systematic curriculum implementation. Meanwhile, concerns related to ethical issues, data security, and algorithmic accountability also have implications for teachers' ability to integrate AI into their teaching practices (Yusof et al. 2022).

However, to date, there remains a lack of comprehensive and systematic studies examining the level of teachers' knowledge and skills in the use of AI, particularly in science teaching. Therefore, a systematic literature review needs to be conducted to identify the challenges and research gaps related to teachers' knowledge and skills in the use of AI for science teaching. This study is important in supporting efforts to empower teachers as catalysts for technology-based educational transformation.

*Research Objectives*

The objectives of this study are as follows:

i. To identify the level of teachers' knowledge regarding the use of artificial intelligence (AI) in Science subjects.
ii. To identify the level of teachers' skills regarding the use of artificial intelligence (AI) in Science subjects.

## Research Methodology

*Research Design*

The article selection process in this study was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which involve four main stages: identification, screening, eligibility, and inclusion. The use of the PRISMA guidelines helps to enhance transparency, systematicity, and reliability in the article selection process. The PRISMA flow diagram used in this study was adapted from Page et al. (2021), as shown in Figure 1.

*Identification*

The first step in a systematic literature review according to the PRISMA guidelines is the identification procedure. In this phase, the focus was on identifying journal articles related to the level of teachers' knowledge and skills regarding the use of artificial intelligence (AI) in science teaching. To achieve this purpose, the authors used specific search strings that were appropriate to the objectives of the study. The search strings were processed using field codes, phrase searching, wildcards, truncation, and Boolean operators (Table 1). These search strings were used in the Scopus and Web of science databases to systematically retrieve relevant articles. The search results identified a total of 988 articles from the Scopus database and 404 articles from Web of science. In addition, a manual search was also conducted through the Google Scholar database. The search identified 64 articles that had the potential

to be included in this study. Therefore, the total number of articles identified from the search was 1,456.

Table 1
*Search Strings for Article Searches in Databases*

| Database | Search strings |
|---|---|
| Scopus | TITLE-ABS-KEY (( "artificial intelligence" OR "AI" ) AND ( "science education" OR "science teaching" OR "Science subject" )) |
| Web of science | TS = ((“artificial intelligence” OR “AI”) AND (“science education” OR “science teaching” OR “Science subject”) ) |
| Google Scholar | ("artificial intelligence" OR "AI" OR "generative AI") AND ("science education" OR "science teaching" OR "science learning") AND ("primary school teachers" OR "elementary teachers" OR "science teachers") |

*Screening*

The screening phase is the second stage in the implementation of the SLR, which aims to filter articles that are truly relevant to the objectives of the study. Of the 1,456 articles identified, 36 duplicate articles were removed. Therefore, a total of 1,420 articles underwent the screening process based on the established selection criteria. At this stage, the articles were examined based on the year of publication, language of publication, and type of publication. A total of 1,274 articles were excluded because they did not meet the established criteria. As a result, 146 articles passed the initial screening process. Of these, 7 articles could not be accessed in full-text form and were excluded from the subsequent process. Therefore, a total of 139 articles were successfully obtained in full-text form to undergo the eligibility assessment process.

Table 2
*Inclusion and Exclusion Criteria for Journal Articles*

| **Category** | **Selection Criteria** | **Exclusion criteria** |
|---|---|---|
| Year of Article | 2022 - 2026 | 2021 and earlier years |
| Language | Malay and English | Languages other than Malay and English |
| Type of Publication | Journal articles | Systematic literature reviews, proceedings, book chapters |

*Eligibility*

The eligibility phase involved a more in-depth analysis of the articles that had passed the screening process. All 139 articles obtained in full-text form were analysed by reviewing the titles, abstracts, methodologies, research findings, and discussions. This assessment aimed to ensure that the selected articles truly met the objectives of the study related to the level of teachers’ knowledge and skills regarding the use of artificial intelligence (AI) in science teaching. The assessment found that 102 articles were excluded because they were less relevant to science education, AI, and teachers’ knowledge and skills. Therefore, a total of 37 articles were identified as meeting the eligibility criteria to undergo quality assessment.

*Article Quality Assessment*

Article quality assessment is an important stage in a systematic literature review to ensure that only articles with adequate methodological quality are selected for analysis. In this study, the quality of the articles was assessed using the Mixed Methods Appraisal Tool (MMAT) developed by Hong et al. (2018). The MMAT is specifically designed to assess studies employing various research designs, including qualitative, quantitative, and mixed-method approaches. Following the screening and eligibility assessment processes, a total of 37 articles proceeded to the quality assessment stage.

All 37 articles were assessed using five main criteria according to their respective research designs. The use of the MMAT enabled the authors to systematically evaluate the methodological quality of the selected articles and determine their suitability for inclusion in the review. Articles that did not meet the established minimum quality requirements were excluded from the final analysis. Based on the quality assessment, 34 articles met the established requirements and were included in this systematic literature review, while three articles were excluded. This process ensured that only articles with adequate methodological quality and reliable findings were included in the subsequent analysis, thereby enhancing the validity and reliability of the study findings.

Table 3
*Assessment Criteria Based on the Mixed Methods Appraisal Tool (MMAT)*

| No. | Criteria | Description | Criteria Code |
|---|---|---|---|
| 1 | Clarity of research questions | The research questions formulated are clear and aligned with the research objectives. | QA1 |
| 2 | Appropriateness of data collection methods | The methods used to collect data are appropriate to the study objectives and capable of addressing the research questions. | QA2 |
| 3 | Relevant sample selection | The sample used is appropriate and reflects the target population of the study. | QA3 |
| 4 | Transparency in reporting and data analysis | The analysis procedures are reported clearly and comprehensively, including considerations of reliability and validity. | QA4 |
| 5 | Assessment of bias and study limitations | The study identifies and discusses potential methodological biases and the measures taken to mitigate them. | QA5 |

Following the quality assessment of all 37 articles using the MMAT, 34 articles met the established methodological and analytical quality requirements and were included in this systematic literature review. Of the 37 articles assessed, 25 met all five assessment criteria, while eight met four criteria. One article met three criteria, one met two criteria, and two met only one criterion. The three articles that met only one or two criteria were excluded from the review, resulting in a final total of 34 articles included for subsequent analysis.

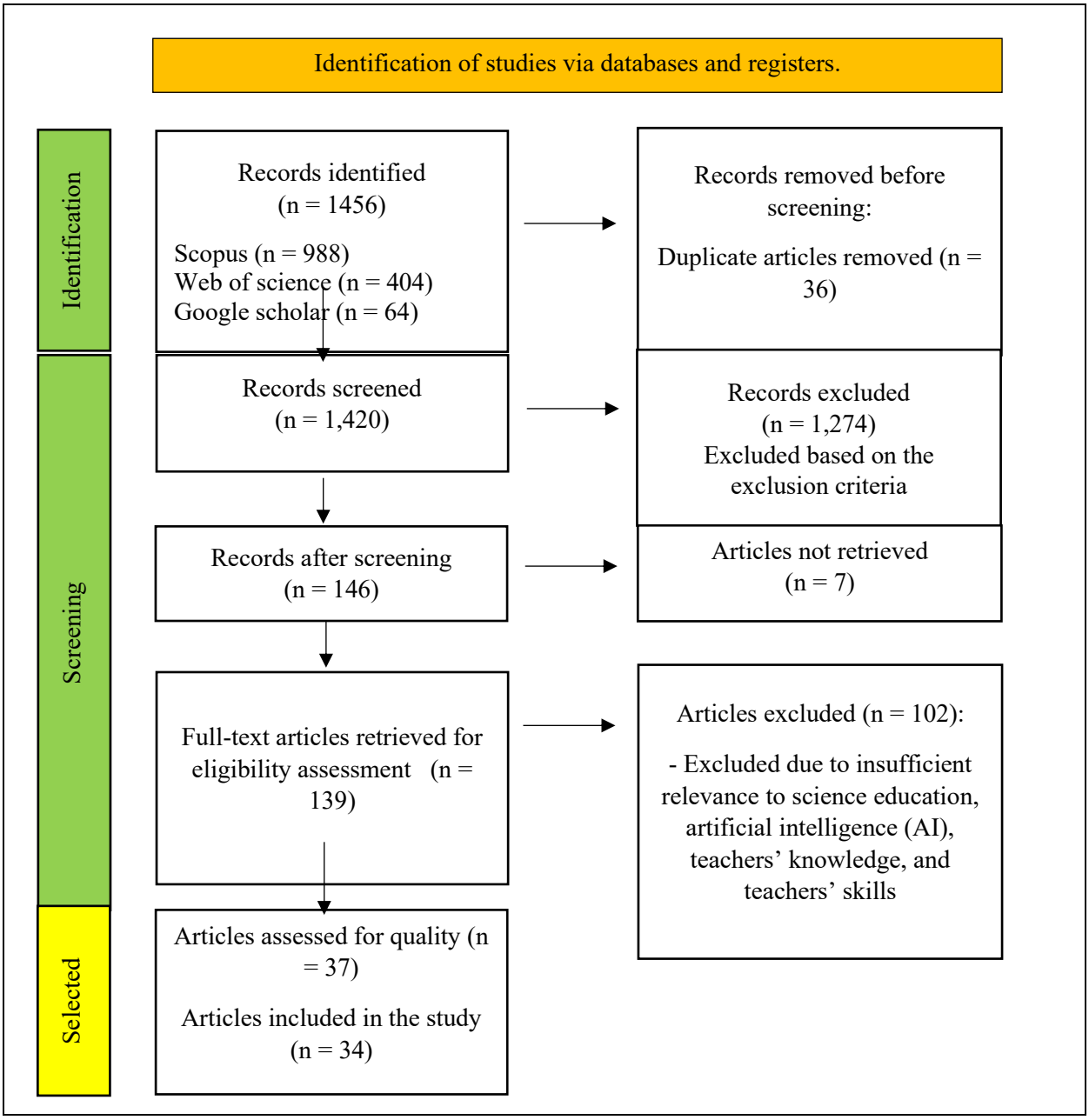



Figure 1 PRISMA Systematic Literature Review Flow Diagram Adapted from Page et al. (2021)

The use of the PRISMA guidelines enhances the transparency and reliability of the article selection process, ensuring that all decisions regarding article inclusion and exclusion are reported systematically and consistently.

Table 4
*Results of the Quality Assessment of Journal Articles*

| No. | Article Author(s) (Year) | Research Design | Country | MMAT Criteria | | | | | Criteria Met | Included in the Review |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | QA1 | QA2 | QA3 | QA4 | QA5 | | |
| 1 | Simbolon, M. et al. (2025) | MX | Indonesia | ✓ | ✓ | ✓ | ✓ | ✗ | 4/5 | ✓ |
| 2 | Nguyen, H. & Hayward, J. (2024) | QL | United States | ✓ | ✓ | ✓ | ✗ | ✗ | 3/5 | ✓ |
| 3 | Mnguni, L. (2025) | QL | South Africa | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 4 | Malakul et al. (2026) | QN | Thailand | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 5 | Blonder, R. et al. , (2024) | MX | Sweden | ✓ | ✓ | ✗ | ✗ | ✗ | 2/5 | ✗ |
| 6 | AlKanaan, H. M. N. (2022) | MX | Saudi Arabia | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 7 | Cooper, G. (2023) | QL | Australia | ✓ | ✗ | C | C | ✗ | 1/5 | ✗ |
| 8 | Cooper, Tang & Fitzgerald (2025) | QN (DC) | Australia | ✓ | ✗ | ✗ | ✗ | C | 1/5 | ✗ |
| 9 | Cooper, G. & Tang, K. S. (2024) | QL | Australia | ✓ | ✓ | ✗ | ✓ | ✓ | 4/5 | ✓ |
| 10 | Ramnarain, U. et al. (2024) | MX | South Africa | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 11 | Pellas, N. (2025) | QN (NR) | Greece | ✓ | ✓ | ✓ | ✓ | ✗ | 4/5 | ✓ |
| 12 | Tang & Cooper (2024) | QL | Australia | ✓ | ✓ | ✓ | ✗ | ✓ | 4/5 | ✓ |
| 13 | Ahmad Shukur Arifen et al. (2024) | QL | Malaysia | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 14 | Park et al. (2023) | MX | Singapore | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 15 | Adli et al. (2024) | QL | Malaysia | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 16 | Yılmaz, Ö. (2024) | MX | Turkey | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 17 | Nugroho et al. (2024) | MX | Indonesia | ✓ | ✓ | ✓ | ✗ | ✓ | 4/5 | ✓ |
| 18 | Nja et al. (2023) | QN (DC) | Nigeria | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 19 | Kotsis (2024) | QL | Greece | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | Li et al. (2026) | MX | China | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 21 | Almasri (2024) | QL | Canada | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 22 | Kim, W. J. (2022) | QL | United States | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 23 | Oh, P. S., & Lee, G. G.(2024) | QL | Korea | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 24 | Zhai, X. et al. (2022) | QN (NR) | United States | ✓ | ✓ | ✓ | ✗ | ✓ | 4/5 | ✓ |
| 25 | Garofalo & Farenga (2024) | MX | United States | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 26 | Henze, J. et al. (2022) | QL | Germany | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 27 | Peikos & Stavrou (2025) | QL | Greece | ✓ | ✓ | ✓ | ✗ | ✓ | 4/5 | ✓ |
| 28 | Kaldaras, L. et al. (2022) | QL | United States | C | ✓ | ✓ | ✓ | ✓ | 4/5 | ✓ |
| 29 | Cheung et al. (2024) | QL | Hong Kong | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 30 | Lee, G. G. et al. (2024) | MX | Korea | ✓ | ✓ | ✓ | ✓ | ✗ | 4/5 | ✓ |
| 31 | Cooper & Tang (2024) | QL | Australia | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 32 | Tang (2024) | QL | Australia | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 33 | Okunade, A. I. (2024) | QL | Nigeria | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 34 | Tang, Cooper & Nielsen (2024) | QL | Australia | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 35 | Lee et al. (2023) | QN (DC) | Korea | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 36 | Li, Haudek & Krajcik (2025) | QN (DC) | United States | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| 37 | Nurul Ezzati Abu Hasan (2026) | QL (CS) | Malaysia | ✓ | ✓ | ✓ | ✓ | ✓ | 5/5 | ✓ |
| Total Number of Articles Included in the Study | | | | | | | | | | n = 34 |

## Research Findings

*Background of the Selected Studies*

*Year of Publication*

Figure 2 shows the distribution of the analysed articles according to year of publication. Based on the figure, 2024 recorded the highest number of publications, with 19 articles. In contrast, 2023 and 2026 recorded the lowest number of publications, with three articles each. Meanwhile, four articles were published in 2022, while five articles were published in 2025. These findings indicate that publications related to the research topic reached their highest level in 2024 compared with the other years within the 2022–2026 period.

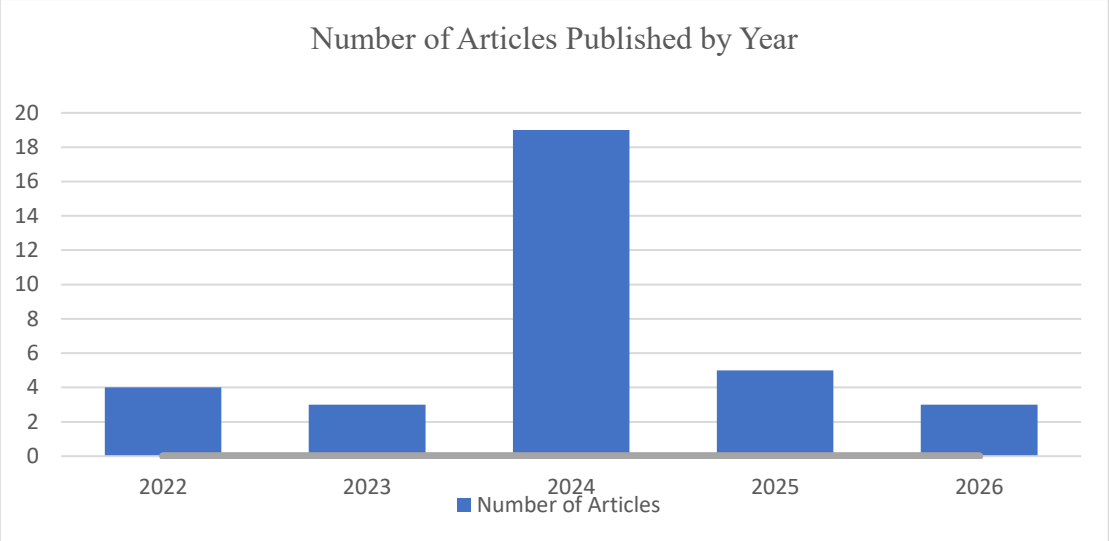



Figure 2 Number of Articles Published by Year

*Research Designs of the Selected Articles*

Based on the analysis of the 34 selected articles, the findings show that the majority of the studies employed a qualitative research design, accounting for 19 articles. This was followed by mixed-method studies, with nine articles, while quantitative research designs were used in six articles. These findings indicate that qualitative approaches were the most commonly employed research design among the selected studies. This may reflect the suitability of qualitative approaches for exploring teachers' experiences, perceptions, and contextual understanding related to the use of artificial intelligence (AI) in science teaching.

Table 5
*Research Designs of the Selected Articles*

| Research Design | Number of Articles | Author(s) |
|---|---|---|
| Qualitative (QL) | 19 | Nguyen, H. & Hayward, J. (2024); Mnguni, L. (2025); Cooper, G. & Tang, K. S. (2024); Tang & Cooper (2024); Ahmad Shukur Arifen et al. (2024); Adli et al. (2024); Kotsis (2024); Almasri (2024); Kim, W. J. (2022); Oh, P. S. & Lee, G. G. (2024); Henze et al. (2022); Peikos & Stavrou (2025); Kaldaras et al. (2022); Cheung et al. (2024); Cooper & Tang (2024); Tang (2024); Okunade, A. I. (2024); Tang, Cooper & Nielsen (2024); Nurul Ezzati Abu Hasan (2026). |
| Mixed Methods (MX) | 9 | Simbolon et al. (2025); AlKanaan (2022); Ramnarain et al. (2024); Park et al. (2023); Yılmaz (2024); Nugroho et al. (2024); Garofalo & Farenga (2024); Lee, G. G. et al. (2024); Li et al. (2026). |
| Quantitative (QN) | 6 | Pellas (2025); Zhai et al. (2022); Nja et al. (2023); Lee et al. (2023); Li, Haudek & Krajcik (2025); Malakul et al. (2026). |

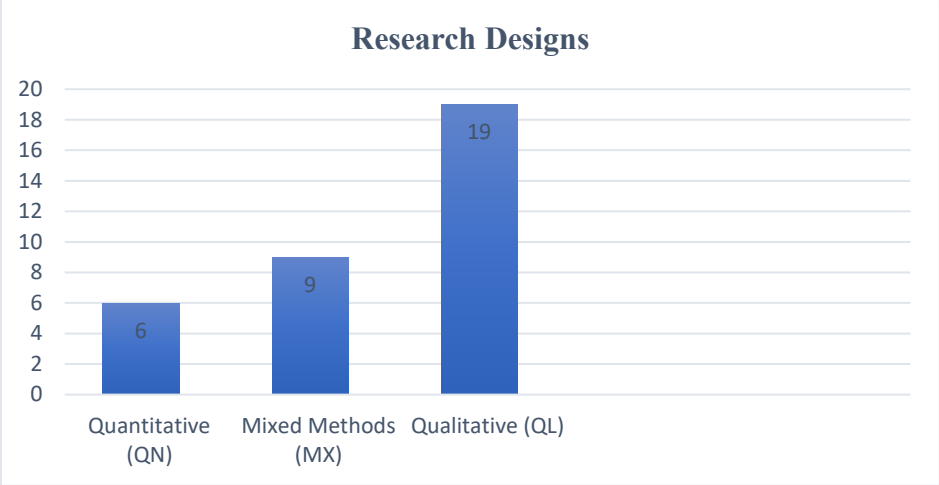



Figure 3 Research Designs of the Selected Articles

*Geographical Focus of the Selected Studies*

Based on the analysis of the 34 selected articles, the United States recorded the highest number of publications, with six articles, followed by Australia with five articles. Greece, Korea, and Malaysia each contributed three articles, while Indonesia, South Africa, and Nigeria each recorded two articles. Meanwhile, Saudi Arabia, Singapore, Turkey, Canada, Germany, Hong Kong, China, and Thailand each contributed one article. Overall, the 34 selected articles represented studies conducted across 16 countries, indicating that research related to the use of artificial intelligence (AI) in science education has been conducted across diverse geographical contexts, with a relatively higher concentration of studies in the United States and Australia.

Table 6

*Geographical Distribution of the Selected Articles*

| Country | Number | Author(s) |
|---|---|---|
| South Africa | 2 | Mnguni, L. (2025), Ramnarain, U. et al. (2024) |
| United States | 6 | Nguyen, H. & Hayward J.(2024), Kim, W. J. (2022), Zhai, X. et al. (2022), Garofalo & Farenga (2024), Kaldaras, L. et al. (2022), Li, Haudek & Krajcik (2025) |
| Saudi Arabia | 1 | AlKanaan, H. M. N. (2022) |
| Australia | 5 | Cooper, G. & Tang, K. S. (2024); Tang & Cooper (2024); Tang (2024); Tang, Cooper & Nielsen (2024); Cooper & Tang (2024) |
| Canada | 1 | Almasri (2024) |
| Germany | 1 | Henze, J. et al.(2022) |
| Greece | 3 | Pellas, N. (2025), Kotsis (2024), Peikos & Stavrou (2025) |
| Hong Kong | 1 | Cheung et al. (2024) |
| Indonesia | 2 | Simbolon, M. et al. (2025), Nugroho et al. (2024) |
| Korea | 3 | Oh, P. S., & Lee, G. G. (2024), Lee, G. G. et al. (2024), Lee et al. (2023) |
| Malaysia | 3 | Ahmad Shukur Arifen et al. (2024), Adli et al. (2024), Nurul Ezzati Abu Hasan (2026). |
| Nigeria | 2 | Nja et al. (2023), Okunade, A. I. (2024) |
| Singapore | 1 | Park et al. (2023) |
| Turkey | 1 | Yılmaz, Ö. (2024) |
| Thailand | 1 | Malakul et al. (2026) |
| China | 1 | Li et al. (2026). |
| Total Number of Articles | | 34 |

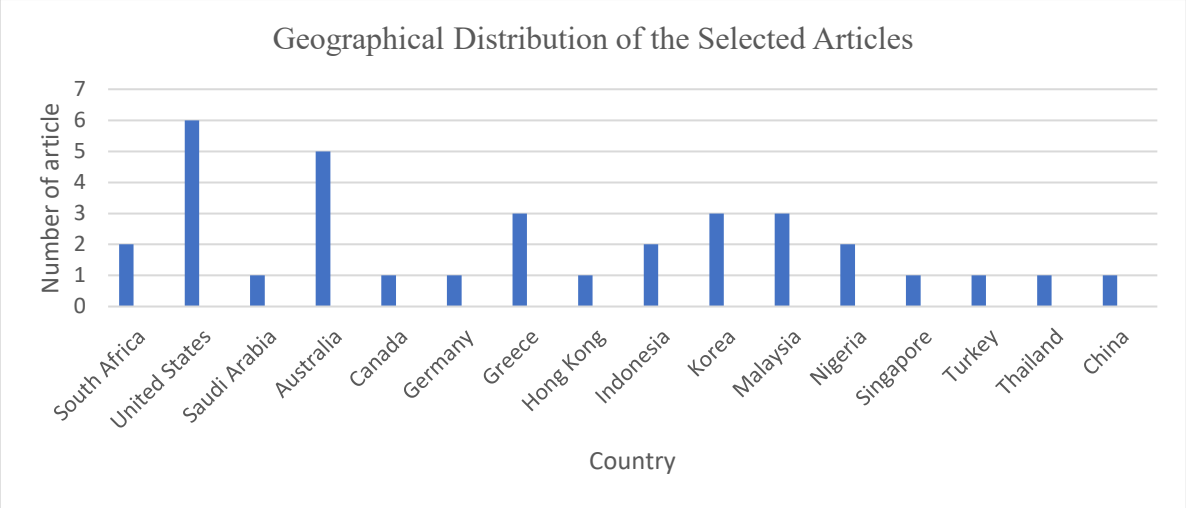



Figure 4 Geographical Distribution of the Selected Articles

*Publication Journals*

The analysis of the 34 selected articles shows that studies related to the use of artificial intelligence (AI) in science education were published across a diverse range of academic journals. *science & Education* and the *Journal of science Education and Technology* recorded the highest number of publications, with seven articles each. Three journals, namely the *Journal for STEM Education Research*, *Frontiers in Education*, and *Asia-Pacific science Education*, each contributed two articles, while the remaining journals were represented by one article each. Overall, the distribution indicates that research on the use of AI in science education has been disseminated across a broad range of academic journals, with a relatively higher concentration of publications in *science & Education* and the *Journal of science Education and Technology*.

Table 7
*Journals of the Selected Articles*

| Journal | Author(s) | Number of Articles |
|---|---|---|
| science & Education | Oh, P. S., & Lee, G. G.(2024), Garofalo & Farenga (2024), Peikos & Stavrou (2025), Cheung et al. (2024), Lee, G. G. et al. (2024), Tang (2024), Tang, Cooper & Nielsen (2024) | 7 |
| Journal of science Education and Technology | Nguyen, H. & Hayward, J. (2024); Cooper, G. & Tang, K. S. (2024); Ramnarain, U. et al. (2024); Tang & Cooper (2024); Cooper & Tang (2024); Li, Haudek & Krajcik (2025); Okunade, A. I. (2024) | 7 |
| Journal for STEM Education Research | Mnguni, L. (2025), Pellas, N. (2025) | 2 |
| Frontiers in Education | Henze, J. et al.(2022), Kaldaras, L. et al. (2022) | 2 |
| Asia-Pacific science Education | Kim, W. J. (2022), Lee et al. (2023) | 2 |
| International Journal of Instruction | AlKanaan, H. M. N. (2022) | 1 |
| Jurnal Pendidikan Bitara UPSI | Ahmad Shukur Arifen et al. (2024) | 1 |
| International Journal of STEM Education | Park et al. (2023) | 1 |

| | | |
|---|---|---|
| Educatum JSMT | Adli et al. (2024) | 1 |
| Educational Technology Quarterly | Yılmaz, Ö. (2024) | 1 |
| Jurnal Ilmiah Pendidikan | Nugroho et al. (2024) | 1 |
| Smart Learning Environments | Nja et al. (2023) | 1 |
| European Journal of Contemporary Education and E-Learning | Kotsis (2024) | 1 |
| Research in science Education | Almasri (2024) | 1 |
| International Journal of Learning, Teaching and Educational Research | Simbolon, M. et al. (2025) | 1 |
| Journal of Research in science Teaching | Zhai, X. et al. (2022) | 1 |
| Malaysian Journal of Social sciences and Humanities (MJSSH) | Nurul Ezzati Abu Hasan (2026) | 1 |
| Discover Education | Malakul et al. (2026) | 1 |
| Computers and Education: Artificial Intelligence | Li et al. (2026) | 1 |
| Total Number of Articles | | 34 |

**Teachers' Knowledge of AI Use in Primary science Teaching**

*RQ1: What is the Level of Teachers' Knowledge Regarding the Use of Artificial Intelligence (AI) in science Subjects?*

Based on the synthesis of the selected studies, teachers' knowledge regarding the use of artificial intelligence (AI) in science teaching can generally be characterised as being at a basic and developing level. Teachers demonstrate awareness of AI and recognise its potential for educational purposes; however, their knowledge of how AI can be meaningfully applied within science teaching remains limited. Tang (2024) highlighted that the use of AI in science education requires an understanding that extends beyond technological functions to include language, interaction, argumentation, and representation in science learning.

Teachers' knowledge of AI also involves understanding how the technology can be applied appropriately in teaching practice. Malakul et al. (2026) identified four interrelated domains of AI competence among science and Technology teachers: human-centred AI, ethics and social impact, knowledge and applications, and classroom implementation. These domains indicate that knowledge of AI involves not only an understanding of the technology itself but also knowledge of its applications, implications, and appropriate use in educational contexts. Another important aspect of teachers' knowledge is their understanding of the accuracy and appropriateness of AI-generated content. Cooper and Tang (2024) highlighted issues concerning how scientific knowledge and representations are generated through generative AI in science education. This suggests that teachers require sufficient knowledge to critically assess AI-generated materials before incorporating them into science teaching, particularly in relation to their accuracy, relevance, and suitability for the intended learning context.

Teachers' knowledge of AI must also be connected to the pedagogical characteristics of science education. Tang and Cooper (2024) emphasised the importance of materiality in

science education in the era of generative AI, as science learning involves not only text-based information but also interaction with physical and material phenomena. Therefore, teachers need to understand the role and limitations of AI in supporting science learning so that the technology complements, rather than replaces, authentic learning experiences.

The development of teachers' AI knowledge is also associated with their experience and exposure to technology. Malakul et al. (2026) found that teachers with greater experience in teaching computer science reported higher levels of AI competence across the domains examined. This finding suggests that technology-related experience may contribute to the development of teachers' knowledge and understanding of AI in educational contexts.

Overall, the synthesis of the selected studies indicates that teachers' knowledge regarding the use of AI in science teaching is at a basic and developing level. While teachers generally possess awareness and basic knowledge of AI, further development is needed in their understanding of its pedagogical applications, limitations, the accuracy of AI-generated content, and its appropriate use in science teaching. Therefore, strengthening teachers' knowledge should focus on developing a more comprehensive understanding of AI that connects technological knowledge with science pedagogical practices, thereby supporting the meaningful and appropriate integration of AI into science teaching.

**Teachers' Skills in Using AI in Primary science Teaching**

*RQ2: What is the Level of Teachers' Skills Regarding the Use of Artificial Intelligence (AI) in science Subjects?*

Based on the synthesis of the selected studies, teachers generally demonstrate limited skills in using artificial intelligence (AI) in science teaching. Although teachers are increasingly exposed to the use of AI in education, they continue to experience difficulties in applying these technologies confidently and effectively in their teaching practices. Park et al. (2023) indicated that many teachers lacked confidence in using AI due to insufficient skills in handling the technology. This finding is supported by Ahmad Shukur Arifen et al. (2024), who emphasised that teachers' skills in using AI are an important factor in determining the effectiveness of its integration into the classroom. Lee et al. (2023) further found that without structured support, teachers experienced difficulties in applying AI effectively in the teaching and learning process. These findings suggest that exposure to AI alone is insufficient if teachers do not possess the necessary skills to integrate it into science teaching.

The use of AI in science education requires not only technical abilities but also the skills to integrate the technology with appropriate pedagogical approaches. Li, Haudek and Krajcik (2025) demonstrated that the use of AI in science teaching requires teachers to understand pedagogical aspects as well as the epistemological implications of AI for the construction of scientific knowledge based on evidence and experimentation. This suggests that skills in using AI are not limited to the ability to operate an application but also involve teachers' ability to evaluate the appropriateness of AI use according to the characteristics and objectives of science learning. Nja et al. (2023) also showed that stress, lack of confidence and uncertainty regarding the use of technology were among the challenges experienced by teachers. These challenges indicate that teachers' skills in integrating AI require further strengthening to enable the technology to be used more effectively in actual teaching contexts.

Teachers' skills are also important when AI is used for assessment and scientific modelling. Li, Haudek and Krajcik (2025) showed that the use of AI to analyse students' scientific representations and models requires the ability to understand relationships among elements within a model and interpret complex information. These requirements indicate that using AI in the context of science assessment demands more specialised skills than the general use of technology. In addition, Tang et al. (2024) showed that the ability to collaborate actively with generative AI (GenAI) as part of teaching or research processes requires new skills among teachers. Therefore, developments in AI within science education create a need for teachers to acquire not only technical skills but also the ability to use, evaluate and adapt AI to pedagogical practices.

Training and professional development are important aspects of improving teachers' skills in using AI. Yılmaz (2024) emphasised the importance of continuous training and guidance to help teachers develop proficiency in using AI across different teaching and learning contexts. Similarly, Nugroho et al. (2024) showed that providing accessible and practical training resources can help improve teachers' ability to use technology in their teaching. Lee et al. (2023) further demonstrated that support through e-learning approaches, including the use of rule-based chatbots, can help build teachers' confidence and competence in teaching complex science concepts. These findings suggest that existing skill limitations can be addressed through systematic, practical and continuous professional development.

Furthermore, skills in using AI involve teachers' ability to adapt the technology to the diverse learning needs of students. Simbolon et al. (2025) showed that the use of chatbots has the potential to increase students' interest in science and assist lower-performing students in understanding scientific concepts more effectively. However, realising this potential requires teachers to possess the skills to manage, guide and adapt the use of AI according to students' needs. Peikos and Stavrou (2025) also highlighted the importance of adapting teaching approaches to students' learning needs. In this context, teachers are not merely users of technology but must possess the skills to determine when, how and for what purposes AI should be used to support science learning. Li et al. (2026) further emphasised the importance of integrating technological and pedagogical aspects to support the effective integration of AI into the teaching and learning process.

Overall, the synthesis of the selected studies indicates that teachers' skills in using AI in science teaching remain limited. Although teachers have demonstrated some exposure to and capabilities in using AI technologies, they continue to face limitations in technical skills, pedagogical integration, assessment and scientific modelling, as well as in adapting AI use to students' learning needs. Tang and Cooper (2024) emphasised the need for a more holistic approach to developing teachers' capabilities, encompassing philosophical, ethical and practical aspects of AI in science education. Zhai et al. (2022) similarly emphasised the importance of integrating AI meaningfully into education rather than merely using it as an additional technological tool. Therefore, structured and continuous professional development is required to strengthen teachers' skills and support them in integrating AI more confidently, meaningfully and effectively into science teaching.

**Discussion of Findings**

This section discusses the main findings derived from the synthesis of the 34 selected articles, with particular emphasis on teachers' knowledge and skills in using artificial intelligence (AI) in science teaching. The findings indicate that teachers' knowledge regarding the use of AI is at a basic and developing level, whereas teachers generally demonstrate limited skills in applying AI in science teaching. This pattern suggests that although teachers have developed awareness and basic knowledge of AI, their practical and pedagogical capabilities in applying AI still require further strengthening.In the context of science education, this is particularly important because the effective use of AI involves not only technological competence but also teachers' ability to connect technology with science content, appropriate pedagogical strategies, and students' learning needs.

AI also has the potential to support the implementation of 21st-century science education by facilitating more interactive, responsive, and student-centred learning. However, the realisation of this potential depends on teachers' ability to select and integrate AI meaningfully into teaching and learning practices. Therefore, the following discussion focuses on the two main findings of this review: teachers' level of knowledge and their level of skills in using AI in science teaching.

*Teachers' Knowledge in Using AI in science Teaching*

The findings indicate that teachers' knowledge regarding the use of AI in science teaching is generally at a **basic and developing level**. Teachers demonstrate awareness of AI and recognise its potential in education; however, their deeper understanding of how the technology can be meaningfully applied within science pedagogy requires further development. This finding is consistent with the synthesis presented in RQ1, which indicates that teachers' knowledge should extend beyond an understanding of the technological functions of AI to include its applications, limitations, and appropriateness within the context of science teaching. Tang (2024), for example, emphasised that the use of AI in science education requires an understanding that extends beyond technological functions to encompass language, interaction, argumentation, and representation in science learning. Malakul et al. (2026) further demonstrated that teachers' AI competence encompasses several interrelated domains, including knowledge and applications, classroom implementation, human-centred AI, and ethics and social impact.

These findings suggest that knowledge of AI should not be viewed solely as technological knowledge. Teachers also need to be able to evaluate the accuracy, appropriateness, and limitations of AI-generated content before incorporating it into their teaching. Cooper and Tang (2024) raised important issues concerning the construction of scientific knowledge and representations through generative AI in science education. In this context, teachers need to recognise that AI-generated content requires critical evaluation before it is used as a learning resource. This requirement is particularly important in science education, where the construction of scientific knowledge is grounded in evidence, representations, observations, and experiences of real-world phenomena.

The findings can also be discussed through the lens of the Technological Pedagogical Content Knowledge (TPACK) framework introduced by Mishra and Koehler (2006). The TPACK framework emphasises that effective technology integration requires an interconnected

understanding of technological knowledge, pedagogical knowledge, and content knowledge. From this perspective, the finding that teachers' AI knowledge remains at a basic and developing level suggests that technological knowledge needs to be connected with pedagogical and content knowledge to support meaningful technology integration. Teachers therefore need to be able to relate their understanding of AI to appropriate pedagogical strategies and the science content being taught. This perspective is also consistent with Tang and Cooper (2024), who emphasised the importance of materiality in science education in the era of generative AI, as science learning involves not only text-based information but also interactions with physical and material phenomena.

In this context, the findings of Li et al. (2026) further highlight the importance of the relationship between technological and pedagogical dimensions in AI integration. This reinforces the view that the development of teachers' AI knowledge should not focus on technological mastery in isolation but should be developed alongside pedagogical and subject-content knowledge. Teachers need to understand not only how an AI technology functions but also when, how, and for what purposes it is appropriate to use it in science teaching. Such an approach can help prevent AI from being used merely as an additional technological tool and instead support its more meaningful integration into the learning process.

Furthermore, experience and exposure to technology appear to be associated with the development of teachers' AI knowledge. Malakul et al. (2026) found that teachers with greater experience in teaching computer science reported higher levels of AI competence across the domains examined. This finding suggests that technology-related experience may contribute to the development of teachers' knowledge and understanding of AI. Consequently, structured and contextualised professional development is important in providing teachers with opportunities to develop AI knowledge through experiences that are directly relevant to their teaching practices. Kotsis (2024) also emphasised the importance of developing teachers' competencies and providing appropriate support as they respond to technological changes in education.

Overall, the findings indicate that teachers' knowledge of AI is at a basic and developing level, with considerable scope for strengthening their understanding of pedagogical applications, technological limitations, the evaluation of AI-generated content, and the appropriate use of AI in science education. From a TPACK perspective, teachers' professional development should move beyond training that focuses solely on how to operate AI applications towards approaches that integrate technology, pedagogy, and science content. Such an approach is important to ensure that the continued development of teachers' AI knowledge supports the meaningful and pedagogically appropriate integration of AI into science teaching.

*Teachers' Skills in Using AI in science Teaching*

The findings indicate that teachers generally demonstrate limited skills in using AI in science teaching. Although teachers are becoming increasingly exposed to AI in educational contexts, many still experience difficulties in applying these technologies confidently and effectively in their teaching practices. These challenges extend beyond technical proficiency to include the ability to integrate AI with appropriate pedagogical approaches. Park et al. (2023) highlighted the importance of teachers' confidence and competence in using AI-related technologies,

while Nja et al. (2023) identified challenges such as stress, uncertainty, and lack of confidence in technology use. These findings suggest that developing teachers' AI skills requires more than technical training; it also requires opportunities for teachers to build confidence and apply AI within authentic teaching contexts.

Teachers' skills in using AI in science education also involve more complex pedagogical capabilities. Teachers need not only to operate AI applications but also to determine how and when these technologies should be used in relation to learning objectives, science content, and classroom contexts. Li, Haudek and Krajcik (2025) demonstrated that the use of AI to analyse students' scientific representations and models requires the ability to interpret relationships between elements within scientific models and make sense of complex information. This illustrates that effective AI use in science education requires skills that combine technological capabilities with pedagogical judgement and an understanding of scientific knowledge construction. The limited skills identified in this review may therefore present challenges to more sophisticated applications of AI, particularly in assessment, scientific modelling, and the analysis of student learning.

These findings can also be interpreted through the lens of Technological Pedagogical Content Knowledge (TPACK). As discussed in Section 6.1, meaningful technology integration involves connections between technological, pedagogical, and content knowledge. In relation to skills, these dimensions need to be translated into teachers' practical ability to select, operate, and adapt AI technologies according to specific learning purposes. Li et al. (2026) highlighted the importance of integrating technological and pedagogical dimensions in supporting the effective use of AI. From this perspective, teachers' AI skills should not be understood solely as the ability to operate technological tools, but also as the ability to integrate those tools appropriately with science pedagogy and content.

Another important dimension concerns teachers' ability to adapt AI to the diverse learning needs of students. Simbolon et al. (2025) showed that chatbots have the potential to stimulate students' interest in science and support lower-performing students in developing a better understanding of science concepts. However, these potential benefits do not arise automatically from the presence of AI technology. Teachers play an important role in determining how AI is managed, guided, and adapted according to students' learning needs. Peikos and Stavrou (2025) similarly highlighted the importance of adapting teaching approaches to learners' needs. Therefore, teachers' AI skills should include the pedagogical ability to determine when, how, and for what purposes AI should be incorporated into science learning.

The findings further highlight the importance of systematic and continuous professional development in strengthening teachers' AI skills. Yılmaz (2024) emphasised the importance of ongoing training and guidance in helping teachers develop their ability to use AI across different teaching and learning contexts. Nugroho et al. (2024) also highlighted the value of accessible and practical training resources in supporting teachers' professional capabilities, while Lee et al. (2023) demonstrated that support provided through e-learning approaches can contribute to teachers' confidence and competence. Collectively, these findings suggest that professional development should move beyond introducing the functions of AI tools and

provide teachers with opportunities to apply AI in pedagogical situations that reflect authentic science teaching practices.

The development of teachers' AI skills should also extend beyond technical and pedagogical considerations. Tang and Cooper (2024) emphasised the need for a more holistic approach to developing teachers' capabilities in the AI era, including considerations related to philosophy, ethics, and the practical application of technology in science education. Zhai et al. (2022) similarly highlighted the importance of meaningful AI integration in education rather than treating AI merely as an additional technological tool. These perspectives suggest that teachers need to develop the capacity to make informed professional judgements regarding the appropriateness, purpose, and implications of AI use in science learning.

Overall, the findings suggest that teachers' skills in using AI in science teaching remain limited, particularly in relation to translating their exposure to AI technologies into effective practical and pedagogical applications. The skills required extend beyond operating AI tools to include pedagogical integration, assessment and scientific modelling, adaptation to students' learning needs, and the meaningful and responsible use of AI. Therefore, teachers' professional development should be structured, practical, and continuous, providing opportunities for teachers to apply AI within authentic science teaching contexts. Such an approach may strengthen teachers' capabilities and support more confident, critical, and meaningful integration of AI into science teaching.

*Conceptual Framework of Teachers' Knowledge and Skills in Using AI in science Teaching*

Based on the synthesis of the reviewed studies, a conceptual framework was developed to illustrate teachers' knowledge and skills in using AI in science teaching. The framework integrates the key findings related to teachers' AI knowledge and skills, together with the supporting factors identified across the reviewed studies. As illustrated in Figure 5, teachers' knowledge and skills represent two key dimensions associated with the integration of AI into science teaching.

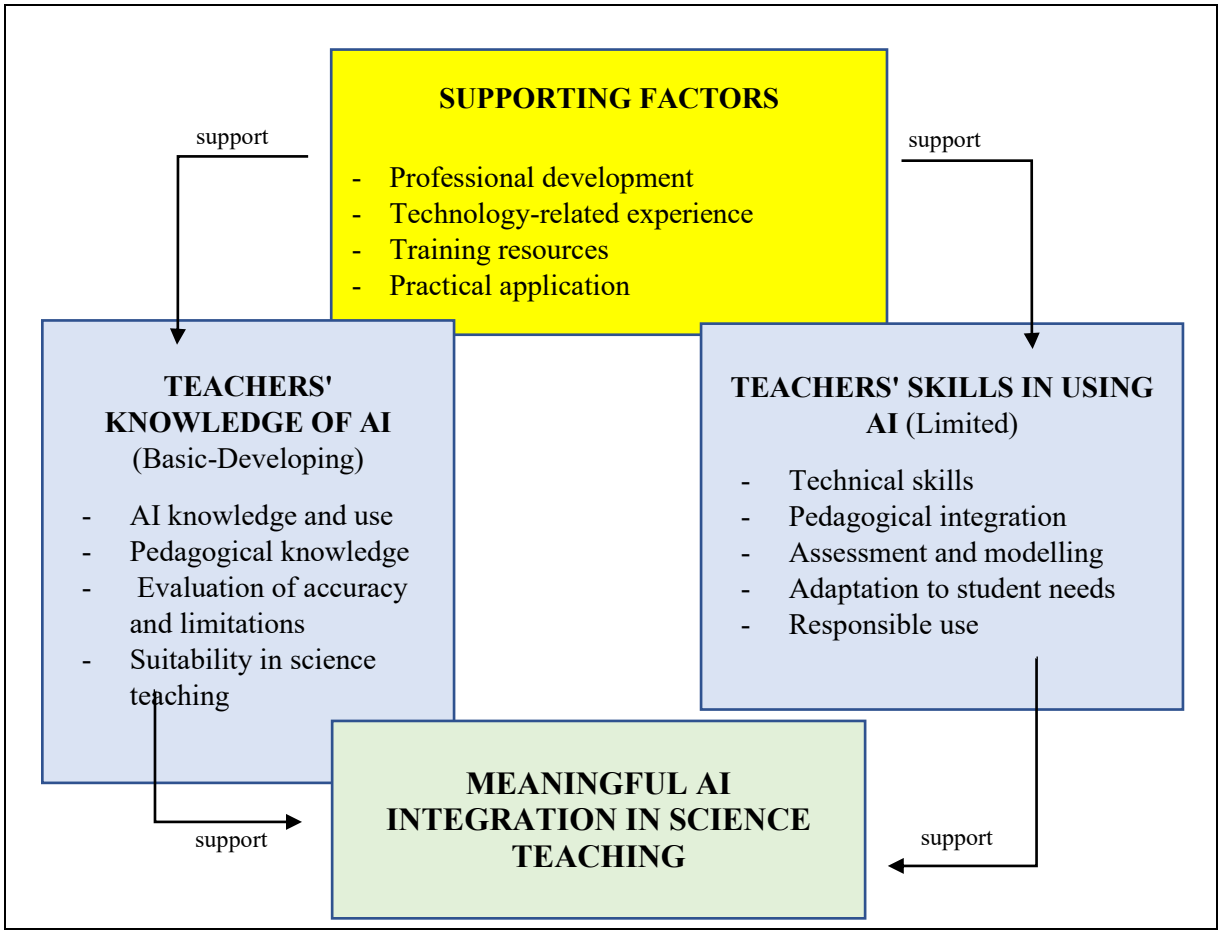



Figure 5 Conceptual Framework of Teachers' Knowledge and Skills in Using AI in science Teaching

As shown in Figure 5, teachers' knowledge of AI is characterised as basic and developing, encompassing knowledge and application of AI, pedagogical knowledge, evaluation of AI accuracy and limitations, and its suitability for science teaching. In contrast, teachers' skills in using AI remain limited, particularly in technical application, pedagogical integration, assessment and modelling, adaptation to students' needs, and responsible use. The reviewed studies also highlight supporting factors, including professional development, technology-related experience, training resources, and opportunities for practical application.

*Research Gaps and Future Research*

Based on the analysis of the 34 selected articles, several research gaps were identified. First, the distribution of research designs indicates a clear predominance of qualitative studies. Of the 34 articles, 19 employed qualitative designs, compared with nine mixed-method studies and six quantitative studies. Although qualitative approaches provide valuable insights into teachers' experiences, perceptions, and contextual understanding of AI use in science teaching, the smaller proportion of quantitative and mixed-method studies indicates an opportunity for future research to employ a broader range of methodological approaches. Future studies could therefore incorporate more quantitative and mixed-method designs to complement qualitative findings and provide a more comprehensive understanding of teachers' knowledge and skills in using AI in science teaching.

Second, the reviewed studies indicate a need for further research that focuses specifically on teachers' knowledge and skills in using AI within the context of science teaching. The synthesis presented in this review shows that teachers' knowledge of AI is still basic and developing, particularly in relation to its pedagogical applications, limitations, and suitability for science teaching. Teachers also demonstrate limited skills in areas such as technical application, pedagogical integration, assessment and modelling, adaptation to students' learning needs, and responsible AI use. These findings highlight opportunities for future studies to examine these dimensions in greater depth and within specific educational contexts. In particular, further research focusing on primary school science teaching would provide more context-specific evidence concerning how teachers understand and apply AI in their teaching practices.

Third, geographical distribution represents another area for further investigation. The 34 selected articles were conducted across 16 countries, with the highest number of studies originating from the United States (six articles) and Australia (five articles). In comparison, three studies were conducted in Malaysia, the same number as in Greece and Korea. Although the presence of Malaysian studies indicates emerging attention to AI within the local educational context, the available evidence remains relatively limited within the overall body of literature reviewed. Future research could therefore further investigate teachers' knowledge and skills in using AI in Malaysian science education, particularly across different school settings and teaching contexts. Such research would contribute additional context-specific evidence concerning the integration of AI into science teaching.

Another area requiring further attention concerns the ethical and responsible use of AI in science education. The reviewed literature indicates that teachers' AI competence extends beyond technological knowledge and includes considerations related to human-centred AI, ethics, social impact, and appropriate classroom implementation. The discussion of teachers' skills similarly highlights the importance of professional judgement concerning the appropriateness, purpose, and implications of AI use in science learning. These dimensions suggest a need for future research to examine more closely how teachers understand and address ethical and responsible AI use within science teaching. Greater attention to these issues could provide a clearer understanding of the knowledge and skills required for teachers to make informed decisions when integrating AI into classroom practices.

Overall, the identified research gaps indicate that research on teachers' knowledge and skills in using AI in science teaching remains an evolving area. Future research would benefit from greater methodological diversity, more context-specific investigations of science teaching, broader evidence from different geographical and educational settings, and further examination of ethical and responsible AI use. Addressing these areas could contribute to a more comprehensive understanding of how teachers develop the knowledge and skills required for meaningful AI integration in science teaching.

**Implications of the Study**

The findings of this systematic literature review have several implications for the professional development of science teachers in the era of artificial intelligence. The finding that teachers' knowledge of AI is at a basic and developing level, while their skills in using AI remain limited, highlights the importance of professional development that extends beyond introducing

teachers to AI technologies. Training should provide opportunities for teachers to develop technological knowledge alongside pedagogical and science-content knowledge, enabling them to understand not only how AI tools operate but also when, how, and for what purposes they can be appropriately integrated into science teaching. This implication is consistent with the findings concerning the importance of technological, pedagogical, and content knowledge in supporting meaningful AI integration.

The findings also have implications for the design of teacher professional development programmes. The reviewed studies highlight the importance of systematic and continuous professional development, accessible training resources, and opportunities to apply AI within authentic teaching contexts. Yılmaz (2024) emphasised the importance of ongoing training and guidance, while Nugroho et al. (2024) highlighted the value of accessible and practical training resources. Lee et al. (2023) further demonstrated the role of structured support in strengthening teachers' confidence and competence. Therefore, professional development related to AI should not focus solely on technical demonstrations but should also provide teachers with opportunities to apply AI to pedagogical situations that reflect actual science teaching practices.

Another important implication concerns the development of teachers' pedagogical judgement when using AI. Teachers need to determine the suitability of AI technologies in relation to learning objectives, science content, classroom contexts, and students' learning needs. The reviewed evidence indicates that effective AI use involves more than technical proficiency; it requires teachers to interpret information, make pedagogical decisions, and adapt AI applications according to specific educational purposes. Li, Haudek and Krajcik (2025), for example, demonstrated the complexity involved in using AI to analyse students' scientific representations and models, while Simbolon et al. (2025) highlighted the potential of AI-supported tools to address different learning needs. These findings suggest that teacher development should incorporate practical opportunities to strengthen pedagogical decision-making in AI-supported science learning.

The study also highlights implications for the critical and responsible use of AI. Teachers require sufficient knowledge to evaluate the accuracy, relevance, limitations, and suitability of AI-generated content before incorporating it into science teaching. The reviewed studies further indicate that AI competence encompasses human-centred considerations, ethics, social impact, and appropriate classroom implementation. Accordingly, professional development should encourage teachers to make informed judgements about the purpose and implications of AI use rather than treating AI merely as an additional technological tool. This is particularly important in science education, where learning involves not only information generated through digital technologies but also engagement with scientific evidence, representations, and physical phenomena.

Finally, the findings have implications for educational institutions and stakeholders responsible for supporting teachers' professional learning. The synthesis indicates that teachers benefit from structured professional development, practical training resources, technology-related experience, and opportunities for practical application. These forms of support can provide teachers with opportunities to progressively strengthen both their knowledge and skills in using AI. In the Malaysian context, these findings may be useful in

informing the planning of professional development initiatives related to AI in science teaching, while recognising that the present review identified only three Malaysian studies among the 34 articles analysed. Further context-specific evidence would therefore be valuable before broader conclusions are drawn regarding implementation within the Malaysian education system.

Overall, the implications of this review emphasise that meaningful AI integration in science teaching requires attention to both teachers' knowledge and practical skills. Professional development should therefore support the integration of technological, pedagogical, and science-content knowledge while also strengthening teachers' ability to critically evaluate, adapt, and responsibly use AI in their teaching practices. Such an approach is consistent with the conceptual framework developed in this review, in which professional development, technology-related experience, training resources, and practical application serve as supporting factors for teachers' knowledge and skills in meaningful AI integration.

**Conclusion**

This systematic literature review synthesised evidence from 34 selected studies to examine teachers' knowledge and skills in using artificial intelligence (AI) in science teaching. Overall, the findings indicate that teachers' knowledge of AI is at a **basic and developing level**, while their skills in applying AI in science teaching remain **limited**. Although teachers demonstrate increasing awareness of AI and its potential applications in education, further development is needed in their understanding of its pedagogical applications, technological limitations, the evaluation of AI-generated content, and its appropriate use in science teaching. In terms of skills, teachers continue to require support in technical application, pedagogical integration, assessment and modelling, adaptation to students' learning needs, and the responsible use of AI. These findings demonstrate that meaningful AI integration in science teaching involves more than familiarity with technological tools; it requires teachers to connect technological capabilities with pedagogical judgement and science-content knowledge.

The review further highlights the importance of professional development in supporting the continued development of teachers' AI knowledge and skills. Structured and contextualised professional learning, technology-related experience, accessible training resources, and opportunities for practical application can provide important support for teachers as they develop their capabilities in using AI. From a TPACK perspective, professional development should therefore extend beyond technical training and provide opportunities for teachers to integrate technological, pedagogical, and science-content knowledge within authentic teaching contexts. At the same time, teachers need to develop the capacity to critically evaluate the appropriateness, accuracy, limitations, and implications of AI use so that the technology can be integrated responsibly and meaningfully into science teaching.

In conclusion, the effective integration of AI into science teaching depends on the continued development of both teachers' knowledge and practical skills. Strengthening these dimensions through appropriate professional support can help teachers move beyond basic awareness and technical use towards more meaningful and pedagogically informed applications of AI. Nevertheless, as research in this area continues to evolve, further studies are needed across different methodological, geographical, and educational contexts to deepen understanding of how teachers develop and apply AI-related knowledge and skills in

science teaching. Such evidence will be important in informing future professional development and supporting the responsible and meaningful integration of AI in science education.

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