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Teachers' Perceptions of Artificial Intelligence (AI)-Supported Science Education: Evidence from Schools

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ABSTRACT

This study examines teachers' perceptions of artificial intelligence (AI)-supported science education in schools in France. An exploratory qualitative design was used to collect responses from teachers through semi-structured questionnaires, and the data were analyzed thematically. Teachers perceived AI as potentially useful for lesson planning, differentiated instruction, formative feedback, and student engagement in science education. However, teachers also identified concerns related to data privacy, algorithmic bias, unequal access to digital infrastructure, limited institutional guidance, and insufficient professional training. Participants emphasized the need to connect AI tools with conceptual understanding, inquiry-based learning, and responsible scientific practice. The study highlights teacher readiness, ethical governance, and equitable infrastructure as essential conditions for sustainable AI integration in science education.

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1. INTRODUCTION

Artificial intelligence (AI) has become one of the most influential technological developments in contemporary education. AI-powered technologies, including intelligent tutoring systems, adaptive learning platforms, learning analytics, virtual laboratories, and generative AI, have transformed how teachers design instruction, assess learning, and support students' academic development (Dillenbourg, 2016; Zhai *et al.*, 2021). Within science education, these technologies provide opportunities to improve scientific inquiry, conceptual understanding, laboratory simulation, data interpretation, and evidence-based reasoning.

Science education aims not only to deliver scientific knowledge but also to develop scientific literacy, critical thinking, experimentation skills, and problem-solving abilities. AI can facilitate these objectives by supporting adaptive learning, immediate feedback, automated assessment, virtual experimentation, and personalized learning pathways (Zhang *et al.*, 2021). Consequently, AI is increasingly viewed as a tool that complements inquiry-based science learning rather than replacing teachers' instructional roles.

Despite these opportunities, successful AI integration depends largely on teachers. Teachers determine how AI technologies are incorporated into lesson planning, classroom interaction, assessment, and learner support. Their perceptions of AI influence classroom implementation, instructional quality, and students' learning experiences. Previous studies have shown that teacher readiness, pedagogical competence, technological confidence, and institutional support are essential for meaningful AI integration (Chan, 2023).

France has demonstrated increasing interest in digital transformation and responsible AI implementation in education. Nevertheless, challenges remain regarding teacher preparedness, digital inequality, ethical governance, and institutional readiness. These challenges become particularly important in science education, where laboratory activities, inquiry-based learning, scientific modelling, and data analysis require responsible and pedagogically appropriate AI implementation.

The Technology Acceptance Model (TAM) proposes that technology adoption depends primarily on perceived usefulness and perceived ease of use (Davis, 1989). However, successful science teaching requires more than technology acceptance. The Technological Pedagogical Content Knowledge (TPACK) framework emphasizes that teachers must integrate technological knowledge, pedagogical knowledge, and disciplinary content knowledge to create meaningful learning experiences (Mishra and Koehler, 2006). Within science education, TPACK enables teachers to connect AI technologies with scientific inquiry, conceptual understanding, laboratory investigation, and evidence-based reasoning.

Although studies on AI in education have increased substantially, research focusing on teachers' perceptions of AI-supported science education within the French educational context remains limited. Existing studies mainly discuss AI adoption, ethical concerns, or educational technology implementation in general education without specifically examining how teachers perceive AI as a resource for science teaching and inquiry-oriented learning. Consequently, empirical evidence regarding AI implementation in science education remains fragmented.

This study aims to examine teachers' perceptions of AI-supported teaching and learning and interpret their implications for science education in France. Specifically, the study investigates teachers' perceptions of AI-supported instructional decision-making, perceived benefits and challenges, institutional readiness, and ethical considerations while discussing how these factors may influence science teaching and inquiry-based learning. The novelty of this study lies in positioning teachers' perceptions of AI within a science education perspective. Rather than discussing AI adoption as a general educational issue, this study integrates AI-supported instruction, inquiry-based science learning, teacher readiness, ethical AI governance, and the TPACK framework to provide context-specific evidence from French schools.

2. LITERATURE REVIEW

2.1. AI in Science Education

AI has become an important component of science education because it enables adaptive instruction, intelligent tutoring, virtual laboratories, automated assessment, and personalized learning experiences. AI technologies assist teachers in monitoring student progress, identifying misconceptions, and providing individualized feedback that supports conceptual understanding (Dillenbourg, 2016; Zhang *et al.*, 2021). These capabilities are particularly valuable in science education, where abstract concepts and experimental reasoning often require multiple forms of representation and continuous formative assessment. Unlike conventional digital learning resources, AI systems analyze learner behaviour and adjust instructional support according to students' needs. This adaptive capability allows science teachers to identify learning difficulties more efficiently while encouraging inquiry-based and evidence-based learning.

2.2. Teacher Readiness for AI Integration

Teacher readiness remains one of the strongest determinants of successful AI implementation in schools. The TAM explains technology adoption through perceived usefulness and perceived ease of use (Davis, 1989). However, educational implementation also requires teachers to possess appropriate pedagogical and disciplinary knowledge. The TPACK framework proposes that meaningful technology integration occurs when teachers combine technological knowledge, pedagogical knowledge, and content knowledge (Mishra and Koehler, 2006). In science education, this integration enables teachers to connect AI technologies with laboratory activities, scientific inquiry, conceptual explanation, experimentation, and problem solving. Professional development therefore becomes essential for preparing teachers to use AI responsibly while maintaining scientific accuracy, instructional quality, and ethical practice.

2.3. AI and Inquiry-Based Science Learning

Inquiry-based learning is one of the central approaches in science education. Students learn scientific concepts by asking questions, designing investigations, interpreting evidence, constructing explanations, and communicating conclusions. AI technologies can strengthen inquiry-based learning through virtual experiments, adaptive simulations, automated feedback, and data visualization. Generative AI systems may also assist students in generating hypotheses, exploring scientific explanations, and comparing alternative solutions. Nevertheless, AI should function as a learning support tool rather than replacing scientific reasoning or experimental investigation. Successful inquiry-based science learning still depends on teachers' guidance, classroom discussion, and students' critical evaluation of scientific evidence.

2.4. Student Engagement and Scientific Literacy

Student engagement is an important predictor of learning outcomes in science education. Interactive AI applications, adaptive learning environments, and simulation-based activities may increase curiosity, motivation, and participation during science learning. However, engagement alone does not guarantee conceptual understanding. Science education aims to develop scientific literacy, including the ability to interpret evidence, evaluate scientific claims, solve problems, and apply scientific knowledge responsibly. Teachers therefore play an essential role in ensuring that AI supports meaningful scientific learning rather than superficial technological interaction.

2.5. Ethical Artificial Intelligence in Science Education

The implementation of AI raises important ethical issues involving privacy, algorithmic bias, transparency, accountability, and responsible data management (Bozkurt *et al.*, 2021; Yu and Yu, 2023). These concerns become particularly significant in science education because AI systems increasingly collect learning analytics, assessment data, and behavioural information from students. Responsible AI implementation requires institutional policies, ethical governance, teacher awareness, and transparent data management. Schools should ensure that AI technologies support educational equity while protecting student privacy and maintaining public trust.

2.6. AI in the French Educational Context

France has increasingly promoted digital transformation while emphasizing responsible AI implementation within schools. Previous studies have highlighted the importance of teacher readiness, institutional support, ethical governance, and regulatory frameworks for successful AI adoption. Nevertheless, empirical evidence describing teachers' perceptions of AI implementation in French classrooms remains limited. Existing research has mainly examined AI adoption from technological or policy perspectives, whereas relatively few studies have investigated how teachers integrate AI into instructional decision-making, particularly within science education.

2.7. Research Gap and Conceptual Position

AI can improve instructional efficiency, adaptive learning, student engagement, and personalized instruction. Other studies emphasize teacher readiness, ethical governance, institutional support, and digital inequality as major determinants of successful implementation. However, three important gaps remain. First, relatively few studies specifically interpret AI implementation from a science education perspective. Second, empirical evidence regarding teachers' perceptions of AI-supported science teaching in France remains limited. Third, previous research has rarely integrated teacher readiness, inquiry-based science learning, ethical AI governance, and instructional decision-making within one conceptual framework. The present study addresses these gaps by examining teachers' perceptions of AI-supported teaching and learning and interpreting their implications for science education. Rather than evaluating AI adoption solely as educational technology, this study positions AI as a pedagogical resource that supports inquiry-based science learning, conceptual understanding, teacher professional development, and responsible classroom implementation.

Table 1 shows that previous research has extensively discussed AI adoption, teacher readiness, and ethical challenges. However, relatively limited attention has been given to interpreting teachers' perceptions within science education. The present study addresses this gap by integrating instructional decision-making, inquiry-based learning, teacher competence, and responsible AI implementation in the French educational context.

Table 1. Synthesis of previous studies and research gap.

RESEARCH AREA	MAIN FINDINGS	LIMITATIONS	CONTRIBUTION OF THE PRESENT STUDY
AI in education	AI improves instructional efficiency and personalized learning	Mainly discusses general education	Focuses on implications for science education
AI-supported assessment	AI facilitates formative assessment and adaptive feedback	Limited classroom-based evidence	Examines teachers' instructional decision-making
Inquiry-based science learning	AI supports scientific investigation and conceptual learning	Few studies investigate teachers' perceptions	Interprets AI within inquiry-oriented science teaching
Teacher readiness	TPACK and professional development influence AI adoption	Mostly quantitative evidence	Provides qualitative evidence from French teachers
AI ethics	Privacy, transparency, bias, and governance are major concerns	Limited context-specific studies	Examines ethical perceptions within French schools
Present study	Integrates AI, teacher perceptions, and science education	—	Provides an integrated framework for AI-supported science education

3. METHODS

This study adopted an interpretive qualitative approach to explore teachers' perceptions of AI-supported teaching and learning and to interpret their implications for science education. An exploratory qualitative design was selected because it enabled participants to describe their experiences, instructional practices, perceived benefits, and challenges associated with AI integration in authentic educational settings (Alharahsheh and Pius, 2020). The study was conducted in educational institutions located in Palaiseau, France. Thirteen teachers participated voluntarily in the study. Participants represented different teaching disciplines, including science, computer science, mathematics, English, and social studies, with teaching experience ranging from one to thirteen years. Although the participants taught different subjects, several were directly involved in science-related disciplines, allowing the broader findings to be discussed in relation to science education while recognizing the multidisciplinary composition of the sample. Data were collected using semi-structured questionnaires containing open-ended questions regarding AI-supported instructional decision-making, classroom implementation, student engagement, perceived benefits, institutional support, infrastructure readiness, and ethical concerns. The questionnaire was designed to encourage participants to explain their classroom experiences while providing examples of AI implementation. The collected responses were analyzed using thematic analysis (Braun and Clarke, 2006). Initially, all responses were read repeatedly to achieve data familiarization. Meaningful statements were then coded and grouped into broader themes according to similarities in participants' responses. Themes were reviewed, refined, and interpreted to identify recurring patterns concerning AI implementation in teaching and learning. The interpretation of the findings was guided by the TAM and the TPACK framework. TAM provided an explanation of teachers' acceptance of AI technologies through perceived usefulness and ease of use (Davis, 1989), whereas TPACK supported interpretation of how technological knowledge, pedagogical knowledge, and content knowledge interact during AI-supported science instruction (Mishra and Koehler, 2006). To improve credibility, participant anonymity and confidentiality were maintained throughout the study. Participation was voluntary, informed consent was obtained before data collection, and participants could withdraw at any stage of the research. No identifying personal information was included in the analysis or presentation of the findings.

4. RESULTS AND DISCUSSION

The thematic analysis identified five major themes describing teachers' perceptions of AI-supported teaching and learning. These themes included AI-supported instructional improvement, student engagement, ethical concerns, institutional readiness, and infrastructure inequality. Collectively, teachers viewed AI as a promising instructional resource while emphasizing that successful implementation depends on pedagogical competence, institutional support, ethical governance, and equitable access to digital infrastructure.

4.1. AI-Supported Instructional Improvement

Teachers consistently perceived AI as a tool that improved lesson preparation, differentiated instruction, and formative assessment. Participants explained that AI reduced the time required to prepare learning materials while enabling teachers to provide more personalized instructional support. Several teachers also emphasized that AI-generated feedback allowed students to receive immediate responses before direct teacher intervention. AI primarily functions as an instructional support system rather than a replacement for teachers. The reported benefits align with previous studies indicating that AI enhances instructional efficiency through adaptive learning, personalized feedback, and automated assessment (Dillenbourg, 2016; Zhang *et al.*, 2021). From a science education perspective, these instructional advantages are particularly valuable because science teachers frequently prepare laboratory activities, inquiry tasks, conceptual explanations, and problem-solving exercises. AI-assisted lesson preparation may therefore allow teachers to devote more time to facilitating scientific discussion, experimentation, and evidence-based reasoning instead of routine administrative work. Although participants acknowledged improvements in lesson preparation and feedback, they expressed greater uncertainty regarding AI's contribution to students' long-term conceptual understanding. Teachers generally agreed that AI could support learning activities but should not replace scientific inquiry, teacher explanation, or classroom discussion. These perceptions reinforce the importance of maintaining teacher-centered pedagogical guidance while integrating AI into science education.

4.2. Student Engagement and Inquiry-Based Science Learning

Most participants reported that AI-supported activities increased students' curiosity, participation, and classroom interaction, particularly during creative and problem-solving activities. Interactive AI applications encouraged students to explore alternative explanations, ask questions, and participate more actively during classroom discussions. Teachers also observed that engagement depended strongly on instructional design rather than technology alone. Participants explained that students initially showed enthusiasm toward AI applications; however, sustained engagement required carefully designed learning activities that connected AI tools with meaningful classroom objectives. This finding is highly relevant to science education because inquiry-based learning depends on active participation, questioning, experimentation, and scientific reasoning. AI technologies may facilitate these learning processes through simulations, adaptive questioning, and immediate feedback, but meaningful inquiry continues to require teacher guidance and pedagogical planning. The relationship between AI and engagement therefore appears indirect. AI provides opportunities for interactive learning, whereas teachers remain responsible for transforming these technological opportunities into scientifically meaningful learning experiences. This interpretation is consistent with TPACK, which emphasizes that technology becomes educationally valuable only when integrated appropriately with pedagogy and disciplinary knowledge (Mishra and Koehler, 2006).

4.3. Ethical Considerations and Responsible AI in Science Education

Ethical concerns emerged as one of the most frequently discussed themes during the interviews. Teachers expressed concerns regarding student privacy, data security, algorithmic bias, transparency, and the reliability of AI-generated information. Several participants emphasized that students might accept AI-generated responses without critically evaluating their scientific validity, potentially reducing opportunities for analytical thinking and evidence-based reasoning. AI should be integrated into science education within an ethical framework that encourages critical evaluation rather than unquestioning acceptance of machine-generated information. Science education aims to develop scientific literacy through observation, experimentation, interpretation of evidence, and logical reasoning. Consequently, AI should function as a supporting tool that stimulates inquiry while maintaining students' responsibility to verify scientific evidence. The concerns expressed by participants are consistent with previous studies emphasizing responsible AI governance, transparency, accountability, and privacy protection in educational environments (Bozkurt *et al.*, 2021). Rather than restricting AI use, teachers suggested establishing institutional policies that promote responsible classroom implementation while protecting students' personal information and encouraging ethical digital citizenship. For science teachers, ethical AI implementation is particularly important because students increasingly use generative AI to obtain scientific explanations, summarize laboratory results, and solve scientific problems. Teachers therefore play an essential role in helping students distinguish between scientifically validated evidence and AI-generated responses that require further verification.

4.4. Institutional Readiness and Professional Development

Participants consistently reported that successful AI implementation depended not only on technology availability but also on institutional readiness. Teachers explained that schools required clearer policies, continuous professional development, administrative support, and opportunities to share experiences regarding AI-supported instruction. Professional development was perceived as particularly important because AI technologies continue to evolve rapidly. Several participants indicated that they possessed basic digital skills but lacked confidence in integrating AI into everyday teaching practices. They also requested practical training that focused on classroom implementation rather than theoretical discussions of emerging technologies. These findings correspond with the TPACK framework, which emphasizes the integration of technological knowledge, pedagogical knowledge, and disciplinary content knowledge (Mishra and Koehler, 2006). Within science education, teachers require sufficient pedagogical competence to connect AI technologies with scientific concepts, laboratory activities, inquiry-based learning, and problem-solving tasks. Institutional readiness therefore extends beyond technological infrastructure. Effective AI integration requires leadership support, curriculum alignment, ethical guidelines, teacher collaboration, and continuous professional learning. Schools that invest in these elements are more likely to achieve sustainable AI implementation than those relying solely on digital infrastructure.

4.5. Digital Infrastructure and Educational Equity

To facilitate interpretation across the identified themes, the major findings from the thematic analysis are summarized in **Table 2**. Teachers generally perceived AI as a valuable instructional support tool. However, sustainable implementation in science education requires teacher readiness, ethical governance, equitable digital infrastructure, and pedagogically appropriate integration. These findings are discussed further in relation to inquiry-based science learning and responsible AI implementation. Teachers also identified unequal access to digital infrastructure as a significant challenge. Participants explained that differences in internet connectivity, hardware availability, software access, and institutional resources affected both teachers' instructional practices and students' learning opportunities. Although the study was conducted in France, participants recognized that disparities in digital access remained evident across schools and student populations. These inequalities may reduce the effectiveness of AI-supported learning because students without reliable digital access cannot benefit equally from adaptive learning systems, virtual laboratories, or AI-assisted instructional resources. From a science education perspective, equitable digital infrastructure is particularly important because AI increasingly supports laboratory simulations, visualization of scientific phenomena, scientific modelling, and inquiry-based investigations. Without adequate technological access, opportunities to experience these instructional innovations become unevenly distributed. Technological innovation should be accompanied by equitable infrastructure development and institutional investment. AI should enhance educational inclusion rather than widening existing educational disparities.

Table 2. Summary of teachers' perceptions of AI-supported teaching and learning.

THEME	FINDINGS	IMPLICATION
AI-supported pedagogy	Teachers reported that AI supported lesson planning, differentiated learning materials, formative feedback, and more efficient instructional preparation.	AI may help science teachers prepare inquiry activities, explanations, and differentiated learning materials.
Student engagement	Teachers observed moderate increases in motivation, curiosity, creative participation, and problem-solving when AI tools were appropriately integrated. They also warned that novelty effects could decline.	Engagement depends on instructional design and teacher guidance rather than AI alone.
Ethical concerns	Participants expressed concerns regarding student-data use, privacy, algorithmic fairness, cultural representativeness of AI training data, transparency, and institutional policy.	Science students should be taught to verify AI-generated scientific information and use AI responsibly.
Infrastructure and inequality	Participants identified unequal internet access, device availability, teacher training, and differences between urban, rural, private, and public schools.	Equitable infrastructure is necessary for fair access to AI-supported science learning.
Teacher readiness	Teachers with prior digital training reported better engagement outcomes, while limited training was associated with hesitation and reduced confidence.	Professional development should integrate technological, pedagogical, and science-content knowledge.
Conceptual understanding	Teachers were less certain that AI produced deep understanding or long-term learning outcomes.	AI should complement teacher explanation, experimentation, scientific inquiry, and critical reasoning.

4.6. Implications for Science Education

AI should be viewed as an instructional resource that complements rather than replaces science teachers. Participants consistently perceived AI as valuable for lesson planning, instructional preparation, personalized feedback, and student engagement, while emphasizing that meaningful learning continues to depend on teacher guidance and classroom interaction. Science education requires students to formulate hypotheses, design investigations, interpret evidence, evaluate alternative explanations, and communicate scientific conclusions. AI can support these learning processes through adaptive instruction, simulation, and automated feedback, but it cannot replace scientific reasoning, experimentation, or collaborative discussion. The study therefore proposes that successful AI integration in science education requires four interconnected components:
(i) teacher readiness and professional competence;
(ii) inquiry-oriented instructional design;
(iii) ethical and responsible AI implementation;
(iv) equitable institutional support and digital infrastructure.

These components create a balanced learning environment in which technological innovation supports, rather than dominates, science teaching and learning.

4.7. Conceptual Components of AI-Supported Science Education

Based on the thematic analysis, this study proposes a conceptual framework describing the relationship between AI implementation and science education. This includes:
(i) Artificial Intelligence Technologies
(ii) Teacher Readiness and Professional Development
(iii) Inquiry-Based Science Teaching
(iv) Student Engagement and Scientific Literacy
(v) Responsible and Ethical AI Use
(vi) Sustainable Science Education

The framework illustrates that technology alone does not improve science education. AI first requires teachers who possess sufficient technological, pedagogical, and disciplinary knowledge. These competencies enable teachers to design inquiry-based science learning that promotes conceptual understanding and scientific reasoning. Student engagement emerges through meaningful instructional activities rather than through technology itself. Ethical governance (including privacy protection, transparency, and responsible AI use) supports sustainable implementation by maintaining trust among teachers and students. Consequently, sustainable science education depends on the balanced interaction among AI technology, teacher competence, pedagogy, ethics, and institutional support. The proposed framework extends previous studies by integrating teachers' perceptions, inquiry-based science learning, ethical AI implementation, and professional readiness within a single conceptual model. It provides a practical perspective for educators and policymakers seeking to implement AI in science education while maintaining scientific integrity, educational equity, and responsible technology use.

5. CONCLUSION

This study explored teachers' perceptions of artificial intelligence (AI)-supported teaching and learning and examined their implications for science education in Palaiseau, France.

Teachers recognized AI as a valuable tool for lesson preparation, differentiated instruction, formative assessment, and student engagement. However, participants emphasized that successful AI integration requires teacher readiness, ethical awareness, institutional support, and equitable digital infrastructure. From a science education perspective, AI should complement inquiry-based learning, scientific reasoning, and conceptual understanding rather than replace teachers' professional judgment. Future research should investigate AI-supported science instruction across diverse educational contexts and evaluate its long-term effects on scientific literacy and learning outcomes.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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