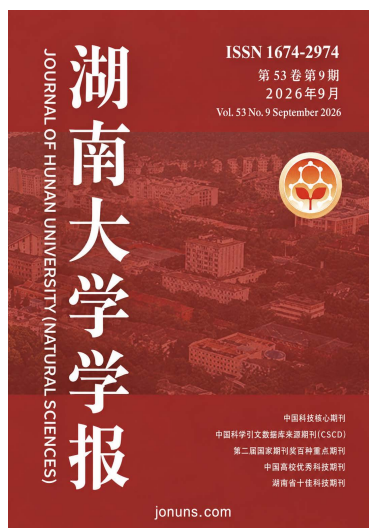




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## Harnessing the Potential of Artificial Intelligence to Enhance Teaching Practices in Moroccan Education

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**Abstract:** This study examines the adoption of artificial intelligence (AI) in Moroccan secondary education, with particular emphasis on teachers' current experiences, perceived benefits, implementation barriers, and expectations regarding AI-supported teaching practices. A descriptive quantitative design was employed using an online questionnaire administered to 156 middle- and high-school teachers in Morocco through non-probability convenience sampling. The questionnaire investigated teachers' use of digital technologies, exposure to AI-based tools, perceived obstacles to AI adoption, and expected educational benefits. Data were analyzed using descriptive statistics, including frequencies, percentages, and distributions.

The findings indicate that AI adoption among the participating teachers remains at an early stage, although many respondents have already experimented with AI-supported applications for content generation, translation, communication, and instructional support. The most frequently reported barrier was insufficient training (33.12%),



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followed by inadequate technological infrastructure (23.00%) and the high cost of AI technologies (18.42%). Participants also identified several potential benefits of AI integration, particularly reduced lesson-preparation time, improved student engagement, enhanced educational content, support for student assessment, and differentiated instruction. Concerns regarding data privacy, ethical use, and equitable access were also reported.

Overall, the findings suggest that the responsible integration of AI into Moroccan secondary education will require sustained professional development, stronger technological infrastructure, appropriate ethical and governance frameworks, and equitable access to digital resources. Given the descriptive design and non-probability sample, the results should be interpreted as evidence of patterns and perceptions among the participating teachers rather than as statistically generalizable conclusions about all Moroccan secondary-school teachers.

**Keywords :** artificial intelligence; secondary education; teacher perceptions; AI adoption; digital pedagogy; Morocco.

## 利用人工智能潜力提升摩洛哥教育中的教学实践

**摘要：**本研究考察人工智能（AI）在摩洛哥中等教育中的应用情况，重点关注教师当前的使用经验、对潜在益处的认知、实施障碍以及对人工智能辅助教学实践的预期。研究采用描述性定量研究设计，通过在线问卷对156名摩洛哥初中和高中教师进行调查，并采用非概率便利抽样方法招募参与者。问卷主要考察教师对数字技术的使用情况、对人工智能工具的接触与使用经验、对人工智能应用障碍的认知，以及对其教育效益的预期。数据分析采用描述性统计方法，包括频数、百分比和分布分析。

研究结果表明，参与调查的教师对人工智能的应用总体仍处于早期阶段，但已有相当一部分教师尝试使用人工智能支持的内容生成、自动翻译、沟通交流和教学辅助工具。最常被提及的应用障碍是培训不足（33.12%），其次是技术基础设施不足（23.00%）以及人工智能技术成本较高（18.42%）。参与者还指出了人工智能融入教育可能带来的多种益处，尤其包括缩短备课时间、提高学生参与度、改善教学内容质量、支持学生学习评价以及促进差异化教学。同时，教师也表达了对数据隐私、伦理使用以及数字技术公平获取等问题的关注。

总体而言，研究结果表明，要实现人工智能在摩洛哥中等教育中的负责任整合，需要持续加强教师专业发展，完善学校技术基础设施，建立适当的伦理与治理框架，并促进数字资源的公平获取。鉴于本研究采用描述性研究设计 and 非概率抽样方法，研究结果应被理解为对参与调查教师群体中相关模式和认知的反映，而不应被视为对所有摩洛哥中等教育教师具有统计意义上的普遍代表性。

**关键词：**人工智能；中等教育；教师认知；人工智能应用；数字教学法；摩洛哥。

### 1. Introduction

The rapid advancement of Information and Communication Technologies (ICTs) is transforming contemporary societies, and the education sector is no exception [1]. Among these technological developments, artificial intelligence (AI) has emerged as an important area of educational innovation, offering potential opportunities to support teaching practices and learning processes [2]. In Morocco, the integration of AI and related digital technologies represents an opportunity to explore ways of modernizing educational practices. However, the extent to which such

technologies can be effectively integrated depends substantially on teachers and their educational contexts. Consequently, understanding AI adoption among Moroccan secondary school teachers is an important area of research [3].

ICTs play a crucial role in Morocco's socio-economic development. Over the past decade, the country has launched several ambitious national initiatives aimed at strengthening digital infrastructure and fostering a robust technological ecosystem. Programs such as Morocco Digital 2015 and Morocco

Digital 2025 have laid the foundation for the Kingdom's ongoing digital transformation strategy [4].

The education sector is fully integrated into this national digital agenda. The development of e-learning and the modernization of teaching methods have become key governmental priorities [5,6], aligned with the national education reform roadmap for 2022–2026 [7]. The implementation of this vision is further supported by Framework Law 51.17 on the education, training, and scientific research system, which provides the legal foundation for educational transformation in Morocco.

This study is significant from academic, practical, and societal perspectives.

**Academic significance.** This research contributes to addressing a gap in the scientific literature within the Maghreb and African contexts regarding the adoption of emerging technologies, particularly artificial intelligence, by secondary school teachers. It provides empirical evidence that may serve as a foundation for future investigations in this field.

**Practical and policy significance.** The study offers valuable insights for policymakers, school leaders, and curriculum developers. The findings can support the design of professional development programs that are better aligned with teachers' needs and the realities of educational practice.

**Societal significance.** By examining the ethical, cultural, and pedagogical implications of AI integration, this study contributes to ongoing discussions concerning educational equity and the future of Moroccan schools in the digital era. It highlights the importance of ensuring that technological innovation serves broader educational objectives and promotes improved learning opportunities for all students.

The specific contribution of this study lies in its focus on a multidisciplinary sample of Moroccan secondary-school teachers, including both middle- and high-school educators. The study jointly examines existing digital practices, current exposure to AI tools, perceived barriers to implementation, expected educational benefits, and practical implications for teacher training and school technological infrastructure. This integrated focus complements previous Moroccan studies that have examined AI perceptions among university teachers, EFL teachers, or other more specific educational groups.

### Research Question

Despite growing recognition of the potential benefits of AI—including personalization, efficiency, and accessibility—its adoption continues to raise important questions among secondary school teachers, who are often confronted with evolving professional roles and concerns regarding established pedagogical practices.

Accordingly, this study seeks to answer the following research question:

In a rapidly evolving educational environment, what are the current trends, challenges, and future prospects associated with the adoption of artificial intelligence by Moroccan secondary school teachers?

## 2. Research Methodology

This section outlines the methodological framework adopted for the study. It presents the target population, sampling procedure, data collection instrument, validation process, and the methods used for data processing and statistical analysis.

### 2.1. Target Population and Rationale for Focusing on Secondary Education

This study investigates the adoption of artificial intelligence (AI) among Moroccan teachers. The target population was deliberately restricted to secondary education teachers, including both middle school and high school educators, while primary school teachers were excluded. This methodological choice was guided by three key considerations specific to the Moroccan educational context.

**Learners' Digital Readiness and Access to Technology**

Secondary school students generally demonstrate higher levels of digital literacy and familiarity with Information and Communication Technologies (ICTs). They are more likely to possess and regularly use digital devices such as computers, tablets, and smartphones, thereby creating an environment that is more conducive to the pedagogical integration and experimentation of AI-based technologies by teachers [8].

**Pedagogical Autonomy of Teachers**

Compared with primary school teachers, secondary school educators typically enjoy greater pedagogical flexibility in designing instructional activities, adapting teaching strategies, and integrating innovative technological tools into their subject-specific practices. This autonomy facilitates the exploration and implementation of AI-supported educational approaches [9].

**Alignment with Educational and Career Pathways**

Secondary education represents a critical stage in students' academic and professional development, as it directly influences access to higher education and future employment opportunities. Investigating AI adoption within this educational level provides valuable insights into how emerging technologies can contribute to preparing students for the competencies and skills required in a rapidly evolving digital society.

### 2.2. Sampling Procedure and Methodological Limitations

The study was conducted using a sample of 156 secondary school teachers. Participants were

recruited through a non-probability, convenience sampling strategy using an online questionnaire distributed through professional teacher networks and educational groups.

Participation was entirely voluntary, and the final sample size was determined by respondents' availability and willingness to participate in the study. This approach facilitated efficient data collection across different educational contexts while ensuring access to teachers with varying levels of experience and technological familiarity.

#### Limitations and Representativeness

As a non-probability sampling method, convenience sampling does not provide all members of the target population with an equal or known probability of selection [10]. Consequently, the findings cannot be generalized to the entire population of Moroccan secondary school teachers with complete statistical confidence.

Furthermore, the study may be subject to self-selection bias, as teachers with a stronger interest in digital technologies and educational innovation may have been more inclined to participate. The sample of 156 respondents provides a descriptive basis for identifying patterns and perceptions within the participating teachers; it does not support statistical generalization to the wider population.

### 2.3. Data Collection Instrument: Design and Validation

The primary instrument used for data collection was a structured online questionnaire specifically developed to investigate teachers' perceptions, experiences, and attitudes toward the use of artificial intelligence in education.

The final questionnaire comprised 14 main items organized into three sections: (1) general information, (2) current use of digital tools, and (3) adoption and perceptions of artificial intelligence. The principal questions were mainly categorical and multiple-choice, with one five-point ordinal item and one open-ended question. A pre-test was conducted with 10 secondary-school teachers to check the clarity and comprehensibility of the items before the questionnaire was administered. Because the instrument was primarily descriptive and categorical in nature, no Cronbach's alpha or other psychometric reliability coefficient was calculated.

To support the clarity and content relevance of the instrument, the questionnaire underwent a pre-test and an expert review process.

#### Linguistic and Syntactic Validation

A language specialist with expertise in French education reviewed the questionnaire to evaluate the clarity, coherence, and comprehensibility of the items.

This review process contributed to eliminating ambiguities, improving sentence structure, and ensuring that the questions could be easily understood by respondents from diverse educational backgrounds.

#### Content and Thematic Validation

An experienced educational practitioner was consulted to assess the relevance and alignment of the questionnaire items with the study objectives and research questions. Based on the expert's recommendations, several modifications were introduced to improve the overall structure of the instrument and to ensure comprehensive coverage of the key dimensions of technology adoption, including perceived benefits, barriers, motivations, and attitudes toward AI integration.

The expert review helped improve the clarity, relevance, and alignment of the questionnaire with the study objectives.

### 2.4. Data Processing and Statistical Analysis

Following the completion of data collection, all responses were exported and organized using Microsoft Excel 365 for data management and statistical analysis.

Microsoft Excel was selected due to its reliability, accessibility, and suitability for processing survey-based quantitative data. The software was used to perform descriptive statistical analyses, including the calculation of frequencies, percentages, and distributions across demographic and thematic variables.

The analysis was exclusively descriptive, using frequencies, percentages, and distributions. No inferential statistical tests were performed.

The results were presented through tables, charts, and graphical representations to describe teachers' use of digital technologies, perceptions of artificial intelligence, barriers to adoption, and perceived educational benefits.

This descriptive approach provided a basis for discussing patterns of AI adoption and teachers' perceptions within the participating sample; it does not permit statistical generalization to all Moroccan secondary-school teachers.

## 3. Results and Discussion

### 3.1. Sample Description

A total of 156 valid responses were collected through the online questionnaire administered to Moroccan secondary school teachers. The demographic and professional characteristics of the respondents are presented below.

#### 3.1.1. Age Distribution

The age distribution of participants reveals a predominance of teachers aged between 25 and 54 years, who collectively represent approximately 86% of the sample. The three age categories within this range are relatively balanced, with proportions varying from 26.92% to 32.05%. This distribution reflects a diverse

population of educators at different stages of their professional careers.

By contrast, respondents under the age of 25 and those aged 55 years or older represent smaller proportions of the sample, accounting for 1.92% and 12.18%, respectively. Overall, the findings indicate a satisfactory level of generational diversity, although middle-aged teachers constitute the dominant group.

Table 1. Age Distribution of Teachers

| Age                | Percentage (%) |
|--------------------|----------------|
| Under 25 years old | 1.92%          |
| 25-34 years        | 26.92%         |
| 35-44 years        | 32.05%         |
| 45-54 years        | 26.92%         |
| 55 years and over  | 12.18%         |

The gender distribution reveals a predominance of male respondents, who account for 63.46% of the sample, compared with 36.54% for female respondents. Although the sample is not gender-balanced, it nevertheless provides valuable insights into teachers’ perceptions of AI adoption within Moroccan secondary education.

3.1.2. Educational Level

The distribution of respondents according to educational level shows a slight predominance of high school teachers, representing 55.77% of the sample, whereas middle school teachers account for 44.23%.

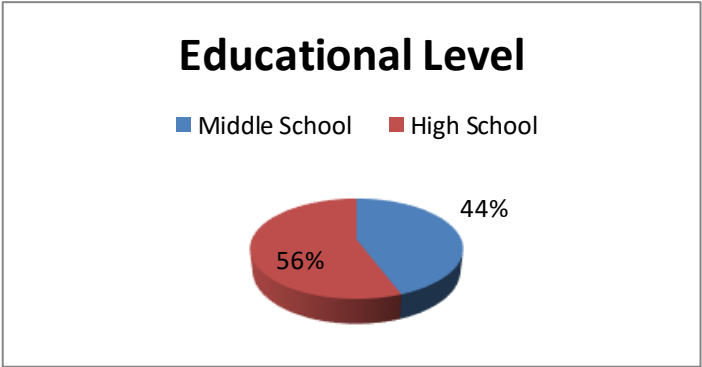


Figure 1. Distribution by Educational Level

This relatively balanced representation ensures that the perspectives collected reflect experiences from both stages of secondary education. The slightly higher participation of high school teachers may be associated with greater exposure to digital technologies and increased engagement with educational innovation initiatives.

3.1.3. Subject Taught

The distribution of respondents across teaching disciplines demonstrates considerable diversity, which

is beneficial for capturing a broad range of perspectives on the integration of artificial intelligence in education.

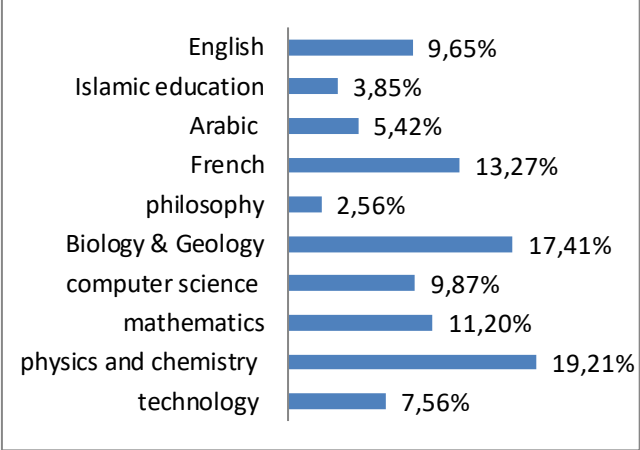


Figure 2. Distribution by Subject Taught

Teachers of Physics and Chemistry (19.21%), Biology and Geology (17.41%), French (13.27%), and Mathematics (11.20%) constitute the largest disciplinary groups represented in the sample. These subjects collectively account for a substantial proportion of respondents and may reflect a stronger interest in educational technologies among teachers working in scientific and language-related disciplines.

Conversely, Philosophy (2.56%), Islamic Education (3.85%), Technology (7.56%), and Computer Science (9.87%) are less represented. Despite these disparities, the disciplinary diversity of the sample enhances the breadth of viewpoints included in the study and contributes to a more comprehensive understanding of AI adoption across different subject areas.

3.1.4. Teaching Experience

Table 2. Distribution of Respondents by Teaching Experience

| Years of Experience | Percentage (%) |
|---------------------|----------------|
| Less than 5 years   | 14.10          |
| 5–15 years          | 39.10          |
| 16–25 years         | 29.49          |
| More than 25 years  | 17.31          |

The distribution of respondents according to teaching experience demonstrates substantial professional diversity.

Approximately 14.10% of participants have less than five years of teaching experience, indicating the inclusion of early-career educators. The majority of respondents (68.59%) have between five and twenty-five years of professional experience, reflecting a strong presence of established practitioners. Additionally, 17.31% of respondents report more than twenty-five years of experience, ensuring that highly experienced educators are also represented.

This diversity enriches the study by incorporating perspectives from teachers with varying levels of

professional expertise, pedagogical practices, and exposure to technological innovation.

3.2. Current Use of Digital Tools

3.2.1. Frequency of Digital Technology Use in Teaching

a. Overall Frequency of Use

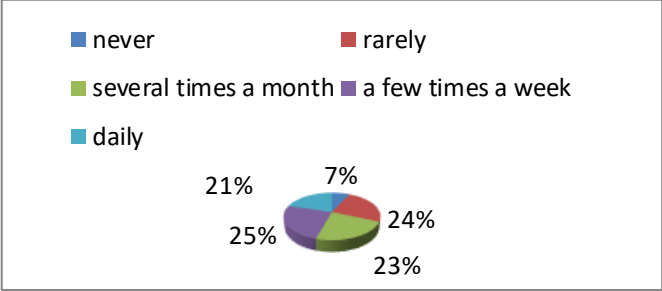


Figure 3. Overall Frequency of Digital Technology Use

The findings indicate that digital technologies have become an integral component of teaching practices for a substantial proportion of Moroccan secondary school teachers.

Approximately 45.59% of respondents reported using digital technologies either daily or several times per week, demonstrating a relatively high level of digital engagement. An additional 23.08% indicated using these technologies several times per month. However, nearly one-third of respondents (31.41%) reported rarely or never using digital technologies in their teaching activities.

These results suggest that although digital tools have gained significant traction within Moroccan secondary education, disparities in usage remain evident. Such differences may be linked to variations in technological access, digital competence, institutional support, and personal attitudes toward educational innovation.

b. Frequency of Use by Educational Level

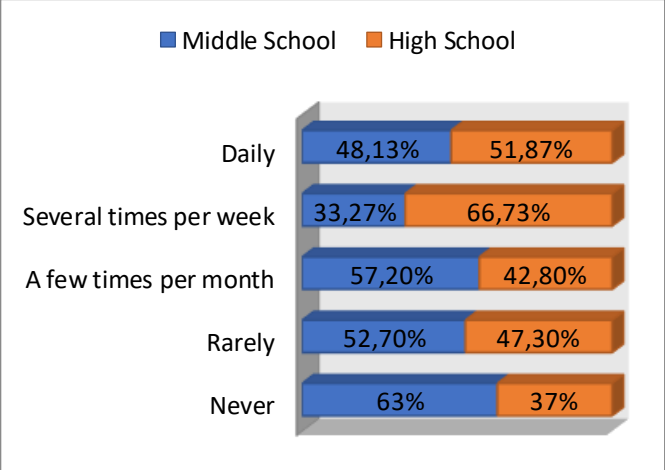


Figure 4. Frequency of Digital Technology Use by Educational Level

Figure 4 clarification: for each digital-technology frequency category, the percentages represent the distribution of middle-school and high-school teachers within that category; therefore, the two percentages sum to 100% for each frequency category.

The comparison between middle school and high school teachers reveals notable differences in patterns of digital technology use.

High school teachers appear more likely to integrate digital technologies into their instructional practices on a regular basis, reporting higher frequencies of daily and weekly use. In contrast, middle school teachers are more frequently represented among respondents who report rare or occasional use.

Several factors may explain this discrepancy, including differences in curriculum requirements, student maturity levels, availability of technological resources, and pedagogical expectations at different educational stages. High school teachers may also face greater pressure to prepare students for higher education environments that increasingly rely on digital competencies.

3.2.2. Types of Digital Tools Used

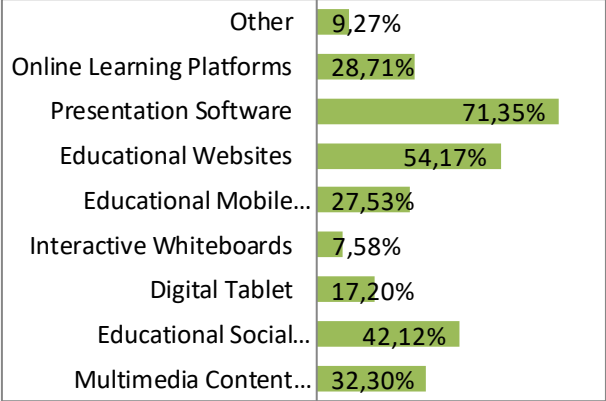


Figure 5. Types of Digital Tools Used in Teaching

The analysis of digital tools currently employed by teachers reveals substantial diversity in educational technology practices.

Presentation software emerged as the most widely used digital resource, reflecting its central role in classroom instruction and content delivery. Educational websites and educational social networks also demonstrated high levels of use, indicating that teachers increasingly rely on online resources to support teaching and learning activities.

The widespread use of these technologies reflects an ongoing transition toward more interactive, collaborative, and learner-centered educational environments. Moreover, the popularity of these tools may be attributed to their accessibility, ease of use, and compatibility with existing teaching practices.

Although many of these technologies can be considered conventional digital tools rather than advanced AI systems, their widespread adoption

demonstrates a growing level of digital readiness among teachers, which may facilitate future integration of artificial intelligence applications into educational settings.

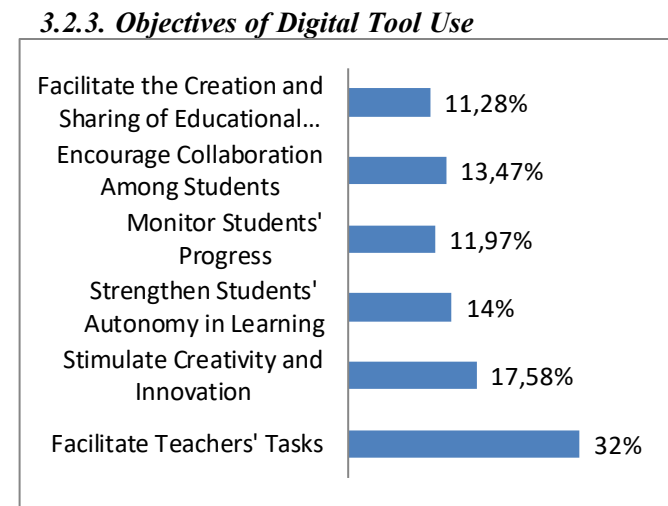


Figure 6. Objectives of Digital Tool Use in Teaching

Teachers reported several motivations for incorporating digital technologies into their instructional practices.

The most frequently cited objective was facilitating teachers’ tasks (31.70%), highlighting the role of digital technologies in reducing administrative workload and improving organizational efficiency. Other important objectives included stimulating creativity and innovation (17.58%), strengthening students’ autonomy in learning (14.19%), encouraging collaboration among students (13.47%), monitoring student progress (11.97%), and facilitating the creation and sharing of educational resources (11.28%).

These findings demonstrate that teachers perceive digital technologies not merely as instructional tools but as instruments capable of enhancing multiple dimensions of the educational process. Beyond improving efficiency, digital technologies appear to support learner engagement, collaborative learning, differentiated instruction, and the development of autonomous learning skills.

Overall, the results indicate that digital technologies are becoming increasingly embedded in Moroccan secondary education. The relatively high frequency of use and the diversity of applications observed suggest that many teachers have already begun integrating digital tools into their professional practices. This growing digital culture constitutes an important foundation for the future adoption of more advanced technologies, including artificial intelligence-based educational tools.

3.3. Adoption of Artificial Intelligence (AI)

3.3.1. Experience with Artificial Intelligence in Teaching

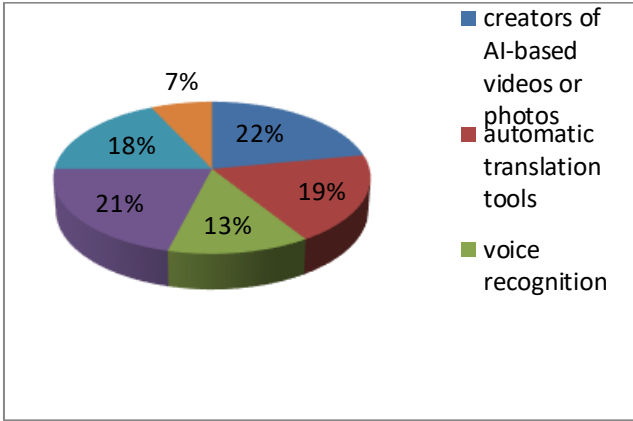


Figure 7. Types of AI-Based Applications and Tools Used by Teachers

The results reveal that Moroccan secondary school teachers are already experimenting with a variety of AI-based applications, although their use remains at a relatively early stage. The most frequently reported tools include AI-powered content generation applications, automatic translation tools, chatbots, voice recognition systems, autocorrection software, and virtual assistants.

These findings suggest that teachers are increasingly exposed to AI technologies through practical applications that support lesson preparation, communication, content creation, and administrative tasks. Rather than replacing traditional teaching practices, these tools appear to function as complementary resources that enhance productivity and instructional effectiveness.

Furthermore, the results indicate a clear relationship between teachers’ level of digital engagement and their likelihood of adopting AI-based technologies. Teachers who reported using digital technologies daily were considerably more likely to have experimented with AI applications, with 57.69% indicating prior use. In contrast, only 20% of teachers who rarely or never used digital technologies reported experience with AI-based tools.

This pattern suggests that familiarity with digital technologies is associated with greater AI adoption. Teachers who regularly integrate technology into their pedagogical practices appear more receptive to innovative digital solutions and demonstrate greater confidence in exploring emerging educational technologies.

3.3.2. Obstacles to the Adoption of Artificial Intelligence in Moroccan Education

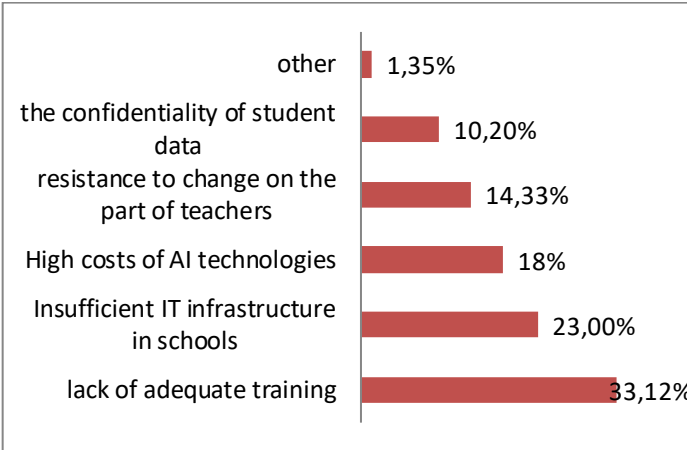


Figure 8. Main Obstacles to the Adoption of Artificial Intelligence in Education

The findings identify several barriers that currently hinder the widespread adoption of AI within Moroccan secondary education.

The lack of adequate training emerged as the most frequently reported obstacle, cited by 33.12% of respondents. This finding highlights the critical importance of professional development programs aimed at strengthening teachers’ AI literacy and technological competencies. Without appropriate training, educators may struggle to understand the pedagogical value of AI tools or to integrate them effectively into classroom practice.

Insufficient technological infrastructure was identified as the second most frequently reported barrier (23.00%). This result reflects persistent disparities in access to digital resources and reliable technological equipment across educational institutions.

Financial constraints also constitute a major challenge, with 18.42% of respondents emphasizing the high costs associated with AI technologies. These concerns are particularly relevant in contexts where educational budgets are limited and technological investments compete with other institutional priorities.

Additional barriers include resistance to change among teachers (14.33%) and concerns regarding student data confidentiality and privacy (10.20%). These findings underscore the importance of addressing both technical and human factors when designing AI implementation strategies. Similar challenges have been identified in previous educational technology studies, where insufficient training, limited infrastructure, and ethical concerns frequently emerge as obstacles to technological innovation [11].

Collectively, these results suggest that the findings point to the potential importance of a comprehensive strategy combining professional development, infrastructure investment, financial support, and clear ethical guidelines.

3.3.3. Perceived Benefits of Artificial Intelligence in Education

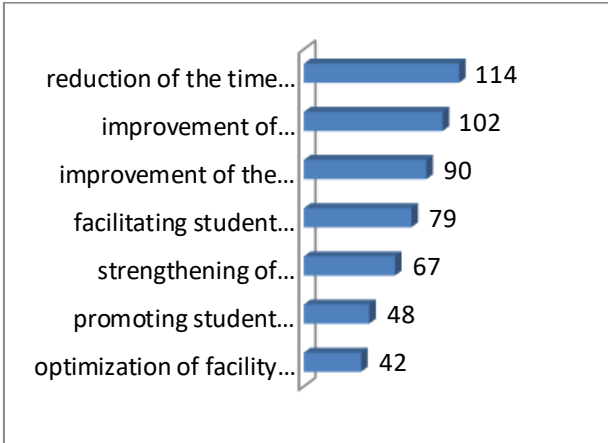


Figure 9. Main Potential Benefits of Artificial Intelligence in Education

Participants identified several potential benefits they associate with the use of AI in education.

The most frequently cited perceived benefit was the reduction of lesson preparation time (114 responses). This response reflects teachers’ expectations that AI could support repetitive and time-consuming tasks.

Perceived improvement in student engagement ranked second (102 responses), indicating that teachers expect AI to have potential for more interactive, motivating, and personalized learning experiences.

Participants also highlighted the potential of AI to improve the quality of educational content (90 responses) and facilitate the assessment of student progress (79 responses). These findings suggest that teachers recognize the capacity of AI to support evidence-based teaching through learning analytics, automated feedback systems, and adaptive instructional resources.

Other frequently mentioned benefits include strengthening differentiated instruction (67 responses), promoting student autonomy through adaptive learning tools (48 responses), and improving school management processes (42 responses).

Taken together, these results reveal a generally positive perception of AI among the participating Moroccan secondary school teachers. While concerns regarding implementation remain important, respondents appear to recognize potential benefits of AI for teaching practice and learning.

4. Discussion

The findings of this study contribute to the growing body of literature examining the integration of artificial intelligence in educational contexts, particularly within developing countries and emerging digital ecosystems.

First, the results show that participating Moroccan secondary-school teachers perceive AI as a promising educational innovation with potential benefits for teaching practice and learning. The benefits identified by participants—including reduced lesson preparation

time, increased student engagement, enhanced content quality, and improved assessment practices—are consistent with previous research emphasizing the pedagogical value of AI-supported learning environments [12].

Second, the study highlights substantial structural and organizational barriers reported by participants, particularly insufficient training, technological infrastructure, and financial constraints. These concerns are consistent with previous studies conducted in both school and higher education contexts [13]. The results suggest that technological availability alone may not be sufficient and that institutional support should be considered when planning implementation efforts.

Third, teachers' perceptions provide valuable insight into the human dimension of technological adoption. The positive attitudes expressed toward AI indicate a willingness among educators to engage with emerging technologies. This finding is consistent with previous research showing that teachers generally view AI as a potentially beneficial tool when adequate support and training are available [14]. Consequently, professional development initiatives should be considered a central component of any national strategy for AI integration.

The study also highlights important ethical considerations. Concerns regarding data privacy and confidentiality demonstrate that teachers are aware of the potential risks associated with the collection, storage, and analysis of educational data. These findings reinforce the need to establish clear ethical frameworks and regulatory mechanisms governing the use of AI in educational settings [15].

More broadly, the results contribute to ongoing discussions regarding the future role of AI in education. Rather than viewing AI as a replacement for teachers, respondents overwhelmingly perceive these technologies as tools capable of augmenting professional practice and supporting pedagogical decision-making. This perspective aligns with recent literature advocating a human-centered approach to AI integration in education [16].

Overall, the responses from participating teachers indicate conditions that may support the gradual exploration of AI in education. Nevertheless, meaningful and sustainable integration would require coordinated efforts involving policymakers, educational institutions, technology providers, and teachers. Investment in teacher training, infrastructure development, ethical governance, and equitable access to digital technologies may help address the barriers reported by participants.

#### **Comparative perspective with international studies**

The findings of this study are broadly consistent with those reported in international research on AI adoption in education. Similar to the present results,

studies conducted in Europe, Asia, and North America have identified lesson preparation support, personalized learning, and student engagement as frequently perceived benefits of AI integration in teaching [12,16]. However, the emphasis placed by participating Moroccan teachers on infrastructure and professional training may reflect differences in educational contexts and levels of technological development. This interpretation should be considered cautiously because the present study is descriptive and does not establish that educational-system development causes differences in teachers' priorities or perceptions.

Furthermore, the importance attributed to teacher training in our study is consistent with findings reported in both developed and developing countries. Previous research has indicated that educators' willingness to adopt AI technologies may be associated with their level of digital competence and confidence in using technological tools [14,20]. In the Moroccan context, the frequency of training-related concerns suggests that professional development is an important consideration for future AI implementation.

Another noteworthy finding concerns the perceived role of AI as a complementary rather than a substitutive technology. Similar conclusions have been reported in recent international studies, which emphasize that teachers continue to view human interaction, emotional support, ethical judgment, and pedagogical decision-making as irreplaceable components of education [15,23]. The convergence between our findings and those reported in the international literature reinforces the argument that the future of AI in education should be based on a collaborative human–AI partnership model. In such a model, artificial intelligence serves as a tool that augments teachers' professional capabilities while preserving the central role of educators in fostering meaningful learning experiences.

#### **Study limitations**

The use of non-probability convenience sampling and voluntary online participation limits the representativeness of the sample. The findings are therefore descriptive and should not be statistically generalized to the broader population of Moroccan secondary-school teachers.

Although this study provides valuable insights into the adoption of artificial intelligence (AI) in Moroccan secondary education, several limitations should be acknowledged when interpreting the findings.

#### **Sample Size and Representativeness**

First, the sample size and sampling approach limit the extent to which the results can be generalized to the entire population of Moroccan secondary school teachers. The participation of 156 teachers provides descriptive information about the respondents' experiences and perceptions, while a larger and more

geographically diverse sample would be needed to assess whether similar patterns occur more broadly.

#### Selection Bias

Second, the use of voluntary participation may have introduced selection bias. Teachers who are already interested in educational technologies or digital innovation may have been more inclined to participate in the study, potentially resulting in more favorable attitudes toward AI than those found within the broader teaching population. Similar limitations have been reported in studies examining AI adoption in teacher education, where motivation and prior technological experience significantly influenced participation patterns [17].

#### Measurement Limitations

Third, several variables examined in this study—such as attitudes toward AI, perceived benefits, and concerns regarding implementation—are inherently subjective and may be influenced by factors not directly measured in the survey. Variables such as institutional culture, digital competence, professional confidence, and previous experiences with technology may affect participants' responses. Similar methodological challenges have been highlighted in previous research on educational technology adoption [18].

#### Context-Specific Findings

Finally, the findings are rooted in the Moroccan educational context and should therefore be interpreted with caution when applied to other countries or educational systems. Educational policies, technological infrastructure, cultural factors, and institutional conditions vary considerably across contexts and may influence both teachers' perceptions and patterns of AI adoption. Nevertheless, comparable concerns regarding technological dependence, critical thinking, and ethical challenges have been reported in international studies investigating AI use in education [19].

Despite these limitations, the study provides an important empirical contribution to understanding the opportunities and challenges associated with AI adoption in Moroccan secondary education. Future research involving larger samples, longitudinal designs, and cross-cultural comparisons would further strengthen the evidence base in this emerging field.

#### Practical and theoretical implications

The findings of this study have important practical and theoretical implications for educational stakeholders, policymakers, and researchers interested in the integration of artificial intelligence into educational systems.

##### Implications for Teaching Practice

The results underscore the importance of continuous professional development in supporting teachers' effective use of AI technologies. Educational institutions should design targeted training programs that move beyond basic technological literacy and focus on developing teachers' pedagogical competence in AI-

enhanced learning environments. Recent studies suggest that AI literacy should become an essential component of teacher professional development frameworks [20].

##### Implications for Technological Infrastructure

The study highlights the critical role of technological infrastructure in facilitating AI adoption. Successful implementation requires reliable internet connectivity, adequate digital equipment, and access to educational software capable of supporting AI-based applications. In Morocco, particular attention should be devoted to reducing disparities between urban and rural schools, as previous studies have documented substantial inequalities in technological access and infrastructure quality [21].

##### Implications for Educational Policy

The findings provide evidence that can inform the development of national policies aimed at promoting the responsible integration of AI into education. Policymakers should establish comprehensive strategies that combine investment in infrastructure, teacher training, and ethical governance frameworks. Furthermore, efforts should focus on ensuring equitable access to AI technologies in order to prevent the widening of existing educational inequalities. Similar concerns have been emphasized in comparative educational research examining technology adoption in resource-constrained environments [22].

##### Theoretical Implications

From a theoretical perspective, this study contributes to the growing body of literature examining the interaction between technological innovation and educational change. The findings support emerging conceptual frameworks that view AI as a transformative educational tool capable of reshaping traditional teaching and learning relationships. Rather than replacing educators, AI appears to reinforce the evolving role of teachers as facilitators, mentors, and learning designers. Recent studies have similarly highlighted the importance of developing human-centered approaches to AI integration that balance technological innovation with pedagogical and ethical considerations [23].

Overall, the study contributes to a deeper understanding of the factors influencing AI adoption in educational settings and provides a foundation for future theoretical and empirical investigations.

##### Suggestions for future research

Given the rapid evolution of artificial intelligence technologies and their increasing relevance to education, several avenues for future research can be identified.

##### Longitudinal Studies on Learning Outcomes

Future studies should investigate the long-term impact of AI integration on student achievement, motivation, and learning outcomes across different educational levels and subject areas. Longitudinal research designs would provide valuable evidence regarding the sustainability and effectiveness of AI-supported educational interventions.

### Classroom Implementation Studies

Further research is needed to examine how teachers actually integrate AI tools into their daily teaching practices. Such studies could identify the most effective implementation strategies, pedagogical approaches, and contextual factors influencing successful adoption.

### International Comparative Research

Comparative studies involving Morocco and other countries would facilitate the identification of best practices and policy models for AI integration. Such research could contribute to a broader understanding of how cultural, institutional, and economic factors influence technology adoption in education.

### Equity and Inclusion

Future investigations should explore the implications of AI for educational equity and inclusion, particularly among students from disadvantaged socioeconomic backgrounds and those attending schools in rural or underserved regions. Understanding how AI affects educational opportunities remains a critical research priority.

### Ethics, Privacy, and Governance

As educational institutions increasingly rely on data-driven technologies, further research should focus on ethical issues related to privacy, transparency, accountability, and data protection. Evaluating existing regulatory frameworks and governance mechanisms will be essential for ensuring the responsible use of AI in education.

### Action Research and Pilot Projects

Collaborative action research involving teachers, school leaders, and researchers could generate practical knowledge regarding the implementation of AI in authentic educational contexts. Pilot projects may provide valuable evidence on both the opportunities and challenges associated with AI-supported teaching and learning.

### Research and Development (R&D)

Future research adopting a Research and Development (R&D) approach could focus on designing, testing, and evaluating AI-based educational solutions specifically adapted to the needs and realities of the Moroccan education system. Such initiatives would contribute to the development of contextually relevant technological innovations capable of supporting national educational priorities.

## 5. Conclusion

Artificial intelligence represents an important technological development with potential implications for the future of education. The findings indicate that participating Moroccan secondary-school teachers perceive AI as having potential to support teaching practices, learning experiences, and educational decision-making.

Participants identified several potential benefits associated with AI integration, including reduced lesson preparation time, perceived improvement in student engagement, enhanced content quality, differentiated instruction, and monitoring of student progress. These findings reflect teachers' perceptions and expectations; the present study did not directly measure student engagement, learning outcomes, or teaching effectiveness.

At the same time, the responses indicate that AI adoption among the participating teachers remains at an early stage. Important challenges were reported, particularly regarding teacher training, technological infrastructure, financial resources, and ethics and data privacy. These findings point to areas that may require attention in future implementation efforts.

Importantly, the findings support a human-centered vision of AI integration. Rather than replacing teachers, AI should be viewed as a complementary tool that enhances professional practice and supports pedagogical decision-making. Teachers remain central to the educational process through their ability to provide guidance, mentorship, emotional support, and meaningful human interaction—elements that technology alone cannot replicate.

Ultimately, the successful integration of AI into Moroccan education will depend on a balanced and strategic approach that combines technological innovation with pedagogical objectives, ethical safeguards, and inclusive educational policies. By investing in teacher capacity building, infrastructure development, and responsible governance frameworks, Morocco can harness the transformative potential of artificial intelligence while ensuring that educational quality, equity, and human values remain at the core of the learning process.

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## Declarations

### Author Contributions

Conceptualization, H.B., H.L., F.E.A. and K.B.; methodology, H.B., H.L., F.E.A. and K.B.; software, H.B. and H.L.; validation, H.B., H.L., F.E.A. and K.B.; formal analysis, H.B., H.L., F.E.A. and K.B.; investigation, H.B., H.L., F.E.A. and K.B.; resources, H.B., H.L., F.E.A. and K.B.; data curation, H.B., H.L., F.E.A. and K.B.; writing—original draft preparation, H.B., H.L., F.E.A. and K.B.; writing—review and editing, H.B., H.L., F.E.A. and K.B.; visualization, H.B., H.L., F.E.A. and K.B.; supervision, H.B., H.L., F.E.A. and K.B.; project administration, H.B., H.L., F.E.A. and K.B. All authors have read and agreed to the published version of the manuscript.

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Ethical review and approval were waived for this study because it involved a voluntary and anonymous survey and did not require Institutional Review Board or Ethics Committee approval.

### Informed Consent Statement

Informed consent was obtained from all participants involved in the study. Participation was voluntary, and participants were informed about the purpose of the study before completing the anonymous questionnaire

### Data Availability Statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical considerations concerning the participants.

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The authors declare that there is no conflict of interest regarding the publication of this manuscript. The authors confirm that all ethical requirements, including plagiarism, informed consent, research misconduct, data fabrication and/or falsification, duplicate publication and/or submission, and redundant publication, have been fully observed.

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