



Training and Institutional Guidelines in Teachers' Adoption of Generative Artificial Intelligence: Bibliometric Analysis, Empirical Evidence, and Implications for Quality Education and Sustainable Development Goals (SDGs)

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ABSTRACT

Generative artificial intelligence (GenAI) is increasingly shaping educational practice, yet teachers' professional adoption remains uneven. This study examines the roles of AI-related training and institutional guidelines in teachers' use of GenAI and situates the findings within the broader context of quality education and the Sustainable Development Goals (SDGs). A cross-sectional survey of 208 Moroccan teachers was analyzed using descriptive statistics, bivariate tests, and binary logistic regression, complemented by a concise bibliometric overview of GenAI research trends. AI-related training was significantly associated with professional GenAI use, whereas institutional guidelines were not significant after adjustment. The findings emphasize the importance of sustained professional development and provide evidence for strengthening responsible GenAI integration in education, particularly in support of SDG 4 on quality education.

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1. INTRODUCTION

Generative artificial intelligence (GenAI) has rapidly become an important technology in education by enabling users to generate, adapt, and interact with content through natural-language prompts. Earlier AI-supported learning applications, including chatbot-based systems, have demonstrated the potential of intelligent technologies to support learning activities, autonomous learning, and access to educational assistance [1, 2]. More recently, GenAI tools have expanded these possibilities for teachers by supporting lesson preparation, content development, idea generation, and other professional tasks. However, teachers' professional adoption of GenAI remains uneven. Access to technology alone does not guarantee meaningful integration because teachers differ in their technological knowledge, confidence, pedagogical readiness, and ability to evaluate AI-generated information. Technology Acceptance Model (TAM) suggests that adoption is shaped by individual perceptions and facilitating conditions [3, 4]. In educational settings, these conditions are especially important because teachers must determine not only whether a technology is useful, but also how it can be applied appropriately within pedagogical practice.

AI-related training is therefore a key factor in teachers' readiness to adopt GenAI. The Technological Pedagogical Content Knowledge (TPACK) framework emphasizes that effective technology integration requires the interaction of technological, pedagogical, and content knowledge [5]. AI literacy is associated with teachers' self-efficacy, ethical awareness, and willingness to engage with AI technologies [6]. Professional development may therefore strengthen the competencies and confidence required for responsible GenAI use.

Institutional guidelines represent another important condition. The Unified Theory of Acceptance and Use of Technology (UTAUT) highlights facilitating conditions as a factor influencing technology use [4]. In the context of GenAI, institutional guidelines may clarify appropriate applications, ethical boundaries, and responsibilities. However, the existence of guidelines does not necessarily ensure their effective implementation. Previous research has similarly emphasized the importance of institutional support while identifying gaps in policy communication and professional preparation [7].

These issues are also relevant to quality education and the Sustainable Development Goals (SDGs), particularly SDG 4. The educational benefits of emerging technologies depend substantially on teachers' capacity to use them responsibly and effectively. Bibliometric studies have shown increasing research attention to digital learning, artificial intelligence (AI), learning quality, and education for SDGs [8, 9]. Understanding the conditions that support teachers' adoption of GenAI can therefore contribute to broader discussions on technology-enabled quality education. Despite increasing research on AI literacy, technology acceptance, professional development, and institutional support, limited empirical evidence has examined how AI-related training and institutional guidelines are jointly associated with teachers' actual professional use of GenAI. In addition, the rapid expansion of GenAI research creates a need to contextualize empirical findings within the broader development of the field.

This study aims to examine the association between AI-related training, institutional guidelines, and teachers' professional use of GenAI. The novelty of this study lies in integrating a concise bibliometric analysis of GenAI research trends with empirical evidence from Moroccan teachers to examine the association of AI-related training and institutional guidelines with actual professional GenAI use, while interpreting the findings in relation to quality education and the SDGs.

Two hypotheses are proposed:

- (i) H1: AI-related training is significantly associated with teachers' professional use of GenAI; and
- (ii) H2: institutional guidelines are significantly associated with teachers' professional use of GenAI.

2. LITERATURE REVIEW

2.1. GenAI Adoption and Teacher Readiness

The integration of AI into education has evolved from earlier intelligent and chatbot-based learning applications toward more flexible generative systems. Chatbot-supported applications have been shown to support language learning and autonomous learning by providing interactive and accessible learning environments [1, 2]. These developments provide an important foundation for understanding the current adoption of GenAI in educational settings. Teacher adoption, however, depends on more than access to technology. The TAM explains technology adoption through perceived usefulness and perceived ease of use [3], while the UTAUT extends this perspective by incorporating facilitating conditions and organizational factors [4]. In the context of GenAI, teacher readiness therefore involves both individual capability and the availability of conditions that support appropriate professional use.

2.2. AI-Related Training and Professional Development

AI-related training is important for strengthening teachers' capacity to use AI effectively in educational practice [10]. At the same time, the expanding applications and growing influence of AI in learning contexts highlight the need for teachers to develop appropriate competencies for its meaningful integration [11]. The TPACK framework emphasizes that meaningful technology integration depends on the interaction among technological, pedagogical, and content knowledge [5]. This perspective is relevant to GenAI because teachers must understand not only how AI tools operate, but also how these tools can be aligned with educational objectives. AI literacy is associated with teachers' self-efficacy, ethical awareness, and willingness to engage with AI [6]. A systematic review of teacher AI training also emphasizes the importance of practical and needs-oriented professional development in strengthening teachers' capacity to use AI effectively [10]. Professional training can enhance the knowledge, confidence, and critical awareness required for responsible GenAI use.

2.3. Institutional Guidelines and Responsible GenAI Integration

Institutional conditions represent another important dimension of GenAI adoption. From a UTAUT perspective, organizational support and facilitating conditions can influence technology use [4]. Institutional guidelines can provide teachers with direction regarding appropriate applications, ethical boundaries, transparency, academic integrity, and professional responsibilities. Research on AI and GenAI adoption in higher education has emphasized the importance of institutional and facilitating conditions [7]. However, the existence of formal guidelines does not necessarily guarantee effective implementation. Their influence may depend on how clearly they are communicated, whether teachers understand their practical implications, and whether the guidelines are supported by professional development and institutional resources. Therefore, examining institutional guidelines separately from AI-related training can help distinguish between organizational provision and individual professional readiness.

2.4. GenAI, Quality Education, and the SDGs

The increasing use of digital and AI-based technologies in education has also been discussed in relation to learning quality and sustainable educational development. Bibliometric research has identified growing scholarly attention to the relationship among language, technology, and student learning quality [8]. Similarly, research on digital learning media has shown an expanding connection between educational technology and education for SDGs [9]. These developments are particularly relevant to SDG 4, which focuses on inclusive and equitable quality education and lifelong learning opportunities. GenAI may contribute to educational innovation, but its potential depends substantially on teachers' capacity to use it critically, effectively, and responsibly. AI-related professional development can strengthen teacher competence, while institutional guidelines can provide an organizational framework for appropriate implementation. In this sense, teacher readiness and institutional support are important conditions for aligning GenAI adoption with broader quality-education objectives.

Table 1 summarizes the principal theoretical and empirical foundations used in this study. Teachers' professional use of GenAI is shaped by the interaction between individual readiness and institutional conditions. Training may strengthen teachers' technological and pedagogical competence, whereas institutional guidelines may provide a framework for responsible implementation. However, relatively limited evidence has examined these two factors simultaneously in relation to teachers' reported professional use of GenAI. This gap provides the basis for the empirical analysis conducted in the present study.

3. METHOD

3.1. Research Design and Participants

This study employed a quantitative cross-sectional survey design to examine factors associated with teachers' professional use of GenAI. The study involved 208 teachers from primary, lower secondary, upper secondary, and higher education institutions in Morocco. Participants were recruited using convenience sampling through professional educational networks. Data were collected anonymously through an online questionnaire administered in French between 9 September 2025 and 9 June 2026. Participation was voluntary.

3.2. Research Instrument and Variables

The questionnaire collected demographic and professional information, including gender, age, teaching discipline, teaching experience, and educational level. AI-related training was assessed by asking whether participants had received specific training on the educational use of AI. Institutional guidelines were assessed by asking whether participants' institutions had established clear policies or guidelines regarding GenAI use. Professional use of GenAI was measured by asking whether participants had used tools such as ChatGPT, Copilot, or Gemini in their professional practice.

3.3. Bibliometric Data

A concise bibliometric overview was conducted using Scopus to examine publication trends related to GenAI using the query TITLE-ABS-KEY (generative AND artificial AND intelligence) taken in July 2026. Annual publication counts were used descriptively to illustrate the development of GenAI research over time. The bibliometric component was intended only to provide a descriptive overview of publication trends and was not designed as a comprehensive bibliometric, citation, or network analysis.

Table 1. Literature related to teachers' adoption of AI and GenAI.

REFERENCE	MAIN FOCUS	KEY CONTRIBUTION	RELEVANCE TO THE PRESENT STUDY
Haristiani <i>et al.</i> [1]	Chatbot-supported language learning	Demonstrates the use of conversational AI technology in educational activities	Provides background on AI-supported learning
Haristiani <i>et al.</i> [2]	Autonomous learning through chatbot applications	Shows the potential of chatbot-based technology to support independent learning	Supports the educational application of intelligent systems
Davis [3]	TAM	Explains adoption through perceived usefulness and perceived ease of use	Provides a theoretical foundation for technology adoption
Venkatesh <i>et al.</i> [4]	UTAUT	Highlights facilitating conditions and organizational influences on technology use	Supports examination of institutional conditions
Mishra and Koehler [5]	TPACK	Integrates technological, pedagogical, and content knowledge	Supports the role of teacher professional competence
Du <i>et al.</i> [6]	Teacher AI literacy	Associates AI literacy with self-efficacy, ethical awareness, and AI engagement	Supports the teacher-readiness dimension
Nikolic <i>et al.</i> [7]	AI and GenAI adoption	Examines attitudes, intentions, behaviors, and facilitating conditions	Supports the institutional and adoption dimensions
Al Husaeni <i>et al.</i> [8]	Technology and learning quality	Links educational technology with learning quality through bibliometric analysis	Supports the quality-education perspective
Fiandini <i>et al.</i> [9]	Digital learning and sustainable development	Maps research linking digital learning with education for SDGs	Supports the SDG-related perspective
Aljemely [10]	Teacher AI training	Reviews challenges and practices in AI-related teacher training	Supports the professional-development dimension

3.4. Data Analysis

Descriptive statistics were used to summarize participant characteristics and the main study variables. Associations between AI-related training and professional GenAI use were examined using the chi-square test of independence, while Fisher's exact test was applied to institutional guidelines because of small, expected cell frequencies. A binary logistic regression model was then used to examine whether AI-related training and institutional guidelines remained associated with professional GenAI use after adjustment for gender, age, educational level, and teaching experience. For the logistic regression analysis, AI-related training was recoded as no training versus received training, and the under-25 age group was combined with the 25-34-year group because of the small number of participants. Adjusted odds ratios, 95% confidence intervals, and p-values were reported, with statistical significance set at $p < 0.05$. Analyses were performed using R software.

4. RESULTS AND DISCUSSION

4.1. Bibliometric overview of GenAI research

A concise bibliometric analysis was conducted to provide a broader context for the empirical investigation of teachers' GenAI adoption. The Scopus search using TITLE-ABS-KEY (generative AND artificial AND intelligence) identified 49,153 documents published between 1972 and 2026. As shown in **Figure 1**, publication activity remained relatively limited for several decades but increased markedly in recent years. The most pronounced growth occurred after 2022, with 2,553 documents recorded in 2023, followed by 8,080 in 2024 and 17,942 in 2025. The database recorded 16,499 documents for 2026 at the time of data collection; this value represents a partial publication year and should therefore not be interpreted as a decline relative to 2025. The rapid increase illustrated in **Figure 1** demonstrates the expanding scholarly attention given to the selected search term. This pattern is consistent with previous bibliometric studies demonstrating growing research attention to technology-supported learning, learning quality, and education for sustainable development [8, 9]. However, publication growth alone does not demonstrate successful educational implementation. The rapid development of the research field also increases the importance of understanding whether teachers have the professional preparation and institutional conditions necessary to integrate GenAI responsibly. The following empirical findings therefore examine teachers' professional use of GenAI, with particular attention to AI-related training and institutional guidelines.

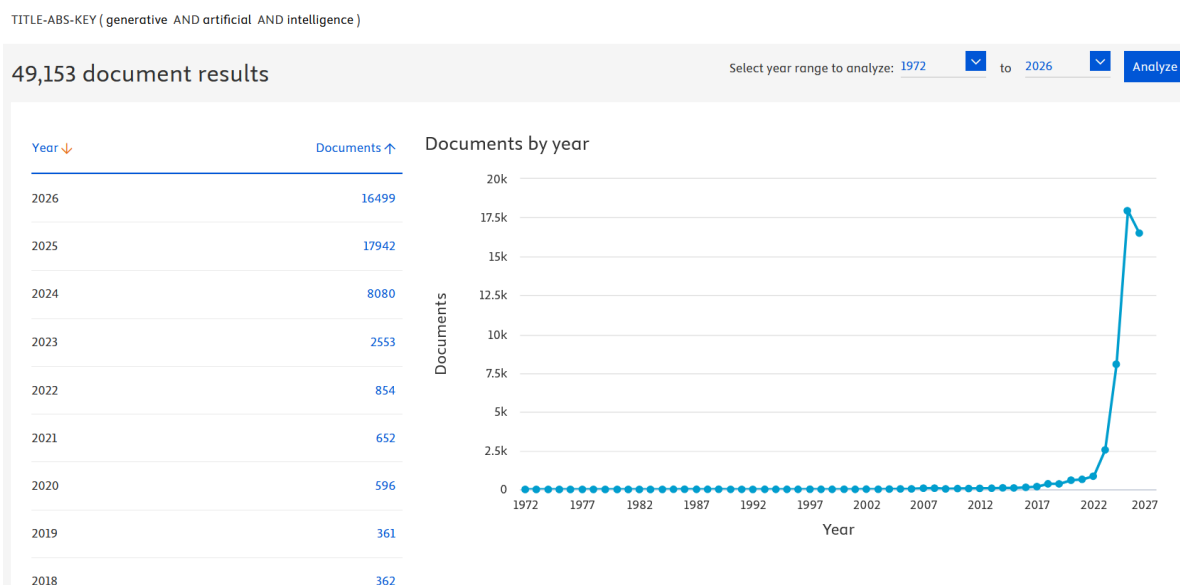


Figure 1. Annual publication trend of GenAI research indexed in Scopus.

4.2. Demographic and professional characteristics

The study included 208 teachers representing different demographic and professional backgrounds. As presented in **Table 2**, the gender distribution was nearly balanced, with 105 women (50.5%) and 103 men (49.5%). 62 teachers (29.8%) were aged 25-34 years and 79 (38.0%) were aged 35-44 years. Only five participants (2.4%) were younger than 25 years, while 46 (22.1%) were aged 45-54 years and 16 (7.7%) were 55 years or older.

Table 2. Demographic and professional characteristics of the participants.

CHARACTERISTICS	CATEGORY	FREQUENCY (n)	PERCENTAGE (%)
Gender	Female	105	50.5
	Male	103	49.5
Age	<25 years	5	2.4
	25-34 years	62	29.8
	35-44 years	79	38.0
	45-54 years	46	22.1
	≥55 years	16	7.7
Educational level	Primary	23	11.1
	Lower secondary	66	31.7
	Upper secondary	63	30.3
	Higher education	56	26.9
Teaching experience	<5 years	35	16.8
	5-10 years	60	28.8
	11-20 years	55	26.4
	>20 years	58	27.9

The participants also represented different educational levels and levels of professional experience. Lower-secondary teachers constituted the largest group (31.7%), followed by upper-secondary teachers (30.3%), higher-education teachers (26.9%), and primary-school teachers (11.1%). Regarding teaching experience, 28.8% had between five and ten years of experience, 27.9% had more than 20 years, 26.4% had between 11 and 20 years, and 16.8% had fewer than five years. Thus, the sample included teachers across multiple educational levels and career stages, providing a varied context for examining professional GenAI adoption.

4.3. AI-related training, institutional guidelines, and professional GenAI use

The descriptive results reveal substantial differences between teachers' exposure to AI-related training, access to institutional guidelines, and actual professional use of GenAI. As shown in **Table 3**, 150 participants (72.1%) reported having received no AI-related training, while 58 teachers (27.9%) reported having received AI-related training.

Institutional guidance was even less common. A total of 165 teachers (79.3%) reported that their institutions did not provide clear guidelines regarding GenAI use, 27 (13.0%) indicated that they did not know whether such guidelines existed, whereas only 16 (7.7%) indicated that such guidelines were available. In contrast, professional GenAI use was relatively widespread: 150 participants (72.1%) reported using GenAI tools professionally, compared with 58 (27.9%) who reported no professional use.

These findings reveal an important contrast between adoption and formal preparation. Although nearly three-quarters of participants reported professional GenAI use, nearly three-quarters had received no AI-related training, and approximately four-fifths reported an absence of institutional guidelines. GenAI adoption may be occurring more rapidly than the development of formal professional and institutional structures intended to support its use.

Table 3. Teachers' AI-related training, institutional guidelines, and professional use of GenAI.

VARIABLE	CATEGORY	FREQUENCY (n)	PERCENTAGE (%)
AI-related training	No training	150	72.1
	Received training	58	27.9
Institutional guidelines	No	165	79.3
	Do not know	27	13.0
	Yes	16	7.7
Professional GenAI use	No	58	27.9
	Yes	150	72.1

From the perspective of TPACK, this pattern is important because access to and use of technology do not necessarily indicate that teachers possess the technological-pedagogical knowledge required for meaningful integration [5]. Similarly, previous research has linked AI literacy with teacher self-efficacy, ethical awareness, and engagement with AI [6], while systematic evidence has emphasized the need for practical and context-sensitive teacher training [10]. The high level of professional use observed alongside limited training therefore raises questions about whether teachers are sufficiently prepared to evaluate AI-generated outputs and integrate them appropriately into professional practice.

The limited availability of institutional guidelines is also notable. UTAUT identifies facilitating conditions as relevant to technology adoption [4], while research on AI and GenAI adoption has highlighted the role of organizational conditions in supporting implementation [7]. Teachers may be adopting GenAI even in settings where formal institutional guidance remains limited. Whether training and institutional guidelines are statistically associated with professional use therefore requires further examination.

4.4. Association between AI-related training and professional GenAI use

The relationship between AI-related training and professional GenAI use was examined using a chi-square test of independence. As presented in **Table 4**, professional use differed substantially across training categories. Among teachers without AI-related training, 99 of 150 (66.0%) reported professional GenAI use. In comparison, 17 of 22 teachers who had received awareness training (77.3%), 16 of 18 teachers who had received basic training (88.9%), and all 18 teachers who had received advanced training (100.0%) reported professional use. The association was statistically significant ($\chi^2 = 12.559$, $df = 3$, $p = 0.006$), indicating that professional GenAI use varied according to teachers' training experience. The significant association between AI-related training and professional GenAI use suggests that professional preparation may play an important role in teachers' engagement with emerging AI technologies. Teachers who had received awareness, basic, or advanced training reported higher levels of professional use than those without training. This pattern is consistent with the TPACK perspective, in which technological knowledge must be integrated with pedagogical and professional knowledge for meaningful technology use [5]. It also aligns with evidence linking AI literacy to teachers' confidence, ethical awareness, and engagement with AI [6]. Furthermore, previous research has emphasized that teacher AI training should be practical and responsive to professional needs [10]. The present findings extend this literature by showing that training is associated not only with readiness or intention but also with teachers' reported professional use of GenAI.

Table 4. Association between AI-related training and professional use of GenAI.

AI-RELATED TRAINING	NON-USE, n (%)	PROFESSIONAL USE, n (%)	TOTAL
No training	51 (34.0%)	99 (66.0%)	150
Awareness training (<2 h)	5 (22.7%)	17 (77.3%)	22
Basic training (2-10 h)	2 (11.1%)	16 (88.9%)	18
Advanced training (>10 h)	0 (0.0%)	18 (100.0%)	18
Total	58 (27.9%)	150 (72.1%)	208

The progressively higher professional use observed across the different levels of AI-related training is also noteworthy. Teachers with awareness, basic, and advanced training reported higher levels of professional GenAI use than teachers without training. Different forms and levels of professional development may therefore provide pathways for developing practical GenAI-related competencies. Nevertheless, the cross-sectional design does not establish that training caused higher GenAI use. Teachers who were already interested in GenAI may also have been more likely to seek training. The adjusted analysis presented subsequently was therefore used to examine whether the association remained after accounting for demographic and professional characteristics.

4.5. Association between institutional guidelines and professional GenAI use

Institutional guidelines were examined as a second potential condition associated with professional GenAI use. Because some expected frequencies were small, Fisher's exact test was used instead of the chi-square approximation. As shown in **Table 5**, 115 of the 165 teachers (69.7%) who reported no institutional guidelines used GenAI professionally. Among teachers who did not know whether institutional guidelines existed, 20 of 27 (74.1%) reported professional use, while 15 of the 16 teachers (93.8%) who reported the presence of institutional guidelines used GenAI professionally. Fisher's exact test indicated that the association was not statistically significant ($p = 0.109$). Thus, institutional guidelines were not significantly associated with professional GenAI use in this sample. Although professional GenAI use was descriptively higher among teachers who reported the presence of institutional guidelines, the overall association did not reach statistical significance.

Table 5. Association between institutional guidelines and professional use of GenAI.

INSTITUTIONAL GUIDELINES	NON-USE, n (%)	PROFESSIONAL USE, n (%)	TOTAL
No	50 (30.3%)	115 (69.7%)	165
Do not know	7 (25.9%)	20 (74.1%)	27
Yes	1 (6.3%)	15 (93.8%)	16
Total	58 (27.9%)	150 (72.1%)	208

This result requires careful interpretation. Institutional guidelines can establish expectations concerning responsible use, transparency, academic integrity, and professional accountability, but their mere existence does not necessarily provide teachers with the competencies required to apply GenAI. From the UTAUT perspective, facilitating conditions concern the broader availability of organizational and technical support rather than the existence of policy documents alone [4]. The present measure captured whether clear institutional guidelines were available, not their content, quality, implementation, teacher

awareness, or enforcement. Consequently, the finding should not be interpreted as evidence that institutional support is unimportant.

The result also highlights a distinction between institutional regulation and professional capacity. Teachers may begin using easily accessible GenAI tools independently before their institutions develop formal policies. This interpretation is consistent with the descriptive results in **Table 3**, where professional GenAI use was widespread despite the limited availability of institutional guidelines. Research examining AI and GenAI adoption has similarly emphasized that organizational conditions form only one component of a broader adoption process [7]. Effective institutional strategies may therefore require guidelines to be accompanied by training, practical support, and opportunities for teachers to develop AI-related competencies.

4.6. Factors Associated with Teachers' Professional GenAI Use

A binary logistic regression analysis was performed to determine whether the observed associations remained after adjustment for demographic and professional characteristics. Professional GenAI use was entered as the dependent variable, while AI-related training, institutional guidelines, gender, age, educational level, and teaching experience were included as independent variables. The results are presented in **Table 6**.

Table 6. Binary logistic regression analysis of factors associated with teachers' professional use of GenAI.

PREDICTOR	CATEGORY	ADJUSTED OR 95% CI		p-VALUE
AI-related training	Received training	3.31	1.36-9.08	0.012
Institutional guidelines	Do not know	1.41	0.53-4.14	0.508
	Yes	5.99	1.06-113.75	0.098
Gender	Female	0.43	0.21-0.89	0.025
Age	35-44 years	0.59	0.21-1.67	0.321
	45-54 years	0.24	0.05-0.98	0.050
	≥55 years	0.13	0.02-0.84	0.036

Note: Reference categories: No training (AI-related training), No (institutional guidelines), Male (gender), and 25-34 years (age).

After adjustment, AI-related training remained significantly associated with professional GenAI use (OR = 3.31, 95% CI: 1.36-9.08, $p = 0.012$). Teachers who had received AI-related training had approximately 3.3 times the odds of reporting professional GenAI use compared with teachers without training. This result supports H1 and strengthens the bivariate finding reported in **Table 4**. Training therefore emerged as the most consistent professional factor associated with GenAI adoption across the analyses.

Gender was significantly associated with professional GenAI use, with female teachers showing lower adjusted odds of professional GenAI use than male teachers (OR = 0.43, 95% CI: 0.21-0.89, $p = 0.025$). Regarding age, teachers aged 35-44 years had lower adjusted odds than the 25-34-year reference group, but this association was not statistically significant (OR = 0.59, 95% CI: 0.21-1.67, $p = 0.321$). Teachers aged 45-54 years also showed lower adjusted odds of professional GenAI use (OR = 0.24, 95% CI: 0.05-0.98, $p = 0.050$), although this result should be interpreted cautiously given its borderline statistical significance. Teachers aged 55 years or older had significantly lower adjusted odds of professional GenAI use (OR = 0.13, 95%

CI: 0.02-0.84, $p = 0.036$). Demographic characteristics may contribute to variation in GenAI adoption, although they were included primarily as adjustment variables rather than as the central focus of this study.

The presence of institutional guidelines did not reach statistical significance in the adjusted model (OR = 5.99, 95% CI: 1.06-113.75, $p = 0.098$); therefore, H2 was not supported. This result reinforces the need to distinguish between having formal guidelines and having effective institutional mechanisms that enable responsible adoption. Professional preparation may have a more direct relationship with teachers' reported use than the mere availability of institutional guidelines.

Educational level and teaching experience were included in the regression model but did not show statistically significant associations with professional GenAI use. Their inclusion nevertheless allowed the relationship between training, institutional guidelines, and professional use to be considered while accounting for differences in teachers' professional backgrounds.

The overall findings provide empirical support for emphasizing professional development in institutional GenAI strategies. From a TPACK perspective, training can help teachers connect technological capabilities with pedagogical purposes [5], while research on AI literacy suggests that knowledge and confidence are important components of teacher engagement with AI [6]. The findings also complement UTAUT by indicating that institutional conditions should not be reduced to the presence of formal guidelines alone [4]. A more comprehensive facilitating environment may require policy, professional development, technical assistance, and opportunities for responsible experimentation.

4.7. Implications for Quality Education and the SDGs

The findings have broader implications for quality education, particularly in relation to SDG 4. The bibliometric trend presented in **Figure 1** demonstrates the rapid expansion of scholarly attention to GenAI, while the empirical findings show that professional adoption among teachers can develop even when formal training and institutional guidance remain limited. This difference between technological diffusion and professional preparation represents an important educational challenge. The contribution of emerging educational technologies to quality education depends not only on their availability but also on educators' capacity to use them effectively [12]. Teachers need the capacity to evaluate AI-generated information, determine its pedagogical relevance, recognize limitations and ethical concerns, and integrate appropriate applications into educational practice. The significant association between AI-related training and professional GenAI use therefore highlights professional development as an important component of responsible digital transformation. This interpretation is consistent with literature emphasizing AI literacy and teacher professional preparation [6, 10].

The findings should not be interpreted as demonstrating that GenAI adoption directly achieves SDG 4. Rather, they identify conditions that may help educational institutions manage GenAI in ways that are more consistent with quality-education objectives. Bibliometric studies connecting educational technology with learning quality and education for sustainable development similarly demonstrate the relevance of digital transformation to broader educational development agendas [8, 9]. Within this context, teacher training can strengthen professional capacity, while institutional guidelines can contribute to governance when they are clear, practical, and accompanied by appropriate implementation mechanisms.

To clarify the relationship between the empirical findings and their broader educational implications, **Table 7** summarizes the main findings, associated challenges, and their relevance to quality education and SDG 4. The combined bibliometric and empirical evidence indicates that the rapid growth of GenAI should be accompanied by deliberate investment in teacher competence and responsible institutional governance. Educational institutions therefore need to move beyond simply permitting or restricting GenAI and instead develop professional-learning opportunities and operational guidance that support pedagogically meaningful and responsible use. Such an approach can contribute to quality education while recognizing that technology itself is not a substitute for teacher competence, pedagogical judgment, or effective educational policy.

Table 7. Implications of the study findings for quality education and SDG 4.

STUDY FINDING	EDUCATIONAL CHALLENGE	PRACTICAL IMPLICATION	RELEVANCE TO QUALITY EDUCATION AND SDG 4
Rapid growth of GenAI research and use	Technological development may advance faster than teacher preparation	Align technological adoption with systematic professional development	Supports more responsible and meaningful digital transformation in education
AI-related training was significantly associated with professional GenAI use	Teachers may adopt GenAI without sufficient pedagogical and critical preparation	Provide continuous AI-related training focused on technological, pedagogical, and ethical competencies	Strengthens teacher capacity and supports the quality of educational practice
Institutional guidelines were not significantly associated with professional GenAI use	Formal policies alone may have limited influence on everyday practice	Combine guidelines with communication, training, resources, and implementation support	Promotes responsible governance rather than policy compliance alone
High professional GenAI use despite limited formal preparation	Informal adoption may create inconsistent practices and uneven levels of competence	Develop structured professional-learning opportunities for teachers	Helps reduce gaps between access to technology and quality of implementation
GenAI adoption does not directly indicate achievement of SDG 4	Technology use may be mistaken for educational improvement	Evaluate GenAI according to pedagogical relevance, teacher competence, and educational outcomes	Keeps quality education as the objective and technology as a supporting mechanism

This study has several limitations. Its cross-sectional design does not allow causal conclusions; the data were self-reported, and convenience sampling may limit generalizability beyond the participating Moroccan teachers. In addition, the bibliometric component was intentionally limited to publication trends rather than comprehensive citation or network analysis. Future studies should employ larger and more diverse samples, longitudinal designs, and broader measures of AI literacy, institutional support, policy implementation, and pedagogical outcomes. Further bibliometric research may also examine thematic development, collaboration networks, and emerging research clusters related to teacher adoption of GenAI.

5. CONCLUSION

This study examined the association between AI-related training, institutional guidelines, and teachers' professional use of GenAI, supported by a concise bibliometric overview of the rapid growth of GenAI research. AI-related training remained significantly associated with teachers' professional GenAI use after adjustment for demographic and professional characteristics, whereas the association with institutional guidelines did not reach statistical significance. These results support H1 but do not support H2.

The findings indicate that professional development may play a particularly important role in strengthening teachers' readiness to use GenAI in educational practice. AI-related training may provide opportunities for teachers to strengthen the technological, pedagogical, and critical competencies needed to evaluate and use AI-generated content responsibly. In contrast, the existence of institutional guidelines alone may be insufficient if such guidelines are not clearly communicated, practically implemented, and supported by relevant professional development.

The rapid increase in GenAI-related publications observed in the bibliometric overview further demonstrates the growing importance of artificial intelligence in education and related fields. However, rapid technological and research development should be accompanied by adequate teacher preparation and institutional capacity. In this context, strengthening AI-related professional development and responsible institutional governance may contribute to the broader objectives of quality education and particularly to SDG 4.

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7. AUTHORS' NOTE

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

8. REFERENCES

- [1] Haristiani, N., Danuwijaya, A. A., Rifai, M. M., and Sarila, H. (2019). Gengobot: A chatbot-based grammar application on mobile instant messaging as language learning medium. *Journal of Engineering Science and Technology*, 14(6), 3158-3173.
- [2] Haristiani, N., Dewanty, V. L., and Rifai, M. M. (2022). Autonomous learning through chatbot-based application utilization to enhance basic Japanese competence of vocational high school students. *Journal of Technical Education and Training*, 14(2), 143-155.
- [3] Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319-340.
- [4] Venkatesh, V., Morris, M. G., Davis, G. B., and Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, 27(3), 425-478.
- [5] Mishra, P., and Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017-1054.
- [6] Du, H., Sun, Y., Jiang, H., Islam, A. Y. M. A., and Gu, X. (2024). Exploring the effects of AI literacy in teacher learning: An empirical study. *Humanities and Social Sciences Communications*, 11(1), 559.

- [7] Nikolic, S., Wentworth, I., Sheridan, L., Moss, S., Duursma, E., Jones, R., Ros, M., and Middleton, R. (2024). A systematic literature review of attitudes, intentions and behaviours of teaching academics pertaining to AI and generative AI (GenAI) in higher education: An analysis of GenAI adoption using the UTAUT framework. *Australasian Journal of Educational Technology*, 40(6), 56-75.
- [8] Al Husaeni, D. F., Al Husaeni, D. N., Ragadhita, R., Bilad, M. R., Al-Obaidi, A. S. M., Abduh, A., and Nandiyanto, A. B. D. (2022). How language and technology can improve student learning quality in engineering? Definition, factors for enhancing students comprehension, and computational bibliometric analysis. *International Journal of Language Education*, 6(4), 445-476.
- [9] Fiandini, M., Nandiyanto, A. B. D., and Agustin, R. R. (2026). Exploring digital learning media research trends in education for sustainable development relating to particle technology: A bibliometric analysis approach. *Journal of Advanced Research Design*, 139(1), 50-73.
- [10] Aljemely, Y. (2024). Challenges and best practices in training teachers to utilize artificial intelligence: A systematic review. *Frontiers in Education*, 9, 1470853.
- [11] Haristiani, N., Al Husaeni, D. N., Herniwati, H., Sugihartono, S., and Abduh, A. (2025). Exploring trends, impact, and applications of artificial intelligence (AI) in language learning: From concept, definition, examples, to a comprehensive bibliometric analysis, *SciEnggJ*, 18, 21-31.
- [12] Ahmed, F. T., Ganiyu, A. A., and Ibrahim, A. (2026). Perceived usefulness and efficacy of learning analytics among science educators for advancing quality education and digital competence to support sustainable development goals (SDGs). *ASEAN Journal for Science Education*, 5(1), 95-102.