education sciences

MDPI

Article

Profiles of Primary School Teachers' Engagement with Generative AI: The Role of Risk, Trust, and Professional Development Needs

Elisabeth Fuchs * and Barbara Lenzgeiger

Primary Education and Didactics, Faculty of Philosophy and Education, Catholic University of Eichstätt-Ingolstadt, 85072 Eichstätt, Germany; barbara.lenzgeiger@ku.de
* Correspondence: elisabeth.fuchs@ku.de

Abstract

The rapid development of generative artificial intelligence (GenAI) is reshaping educational practice, yet little is known about how primary school teachers perceive and engage with these technologies. This study examined primary school teachers' perceived risks, trust in AI, professional development (PD) needs, and patterns of AI use. Data were collected through a survey of 295 primary school teachers. Hierarchical and k-means cluster analyses were conducted to identify distinct profiles of AI engagement. The results indicate a state of cautious openness characterized by moderate to high perceived risks, relatively low trust, and substantial PD needs. Three profiles emerged: Skeptical Rejecters, Interested but Uncertain, and Trusting Learners. The profiles differed significantly in their current and intended use of AI. Across all profiles, intended use exceeded actual implementation, indicating an intention-usage gap. Notably, the highest PD needs were reported by the Interested but Uncertain profile rather than by the most skeptical teachers. The findings highlight the heterogeneity of primary school teachers' engagement with GenAI and suggest that professional development should support both AI-related competencies and informed professional judgment when integrating AI into educational practice.

Keywords: generative artificial intelligence; primary education; teacher professional development; trust in AI; perceived risks; technology adoption; teacher profiles; cluster analysis

Academic Editors: Anna Mavroudi, Kyparisia Papanikolaou and Charoula Angeli

Received: 28 July 2026
Revised: 25 August 2026
Accepted: 27 August 2026
Published: 1 September 2026

1. Introduction

The rapid development of generative artificial intelligence (GenAI), particularly large language models such as Claude, Gemini, and ChatGPT, has significantly reshaped the discourse on digital technologies in education. While artificial intelligence has been part of educational research for several years, particularly in the form of intelligent tutoring systems and adaptive learning technologies, its evolution from early systems to widely accessible, general-purpose tools marks a qualitative shift (Murphy, 2019; Roll & Wylie, 2016). Since 2022, GenAI has transitioned from a specialized technology to an increasingly ubiquitous presence in educational contexts (Scheiter et al., 2025).

Generative artificial intelligence is considered to have far-reaching implications for teachers and teaching (Heeg & Avraamidou, 2023), as it is already reshaping educational practice and is expected to play an increasingly important role in the teaching profession (Hodges & Kirschner, 2024). This development poses new challenges for teachers,

including those working in primary education (Harry & Sayudin, 2023). Unlike higher educational levels, primary schooling is characterized by foundational learning processes and heightened ethical responsibilities (Favero et al., 2026; Kantreiter et al., 2024). The use of GenAI in this context raises concerns related to the development of basic skills, data privacy, and the vulnerability of young learners (Burns et al., 2026; Nuryani et al., 2026). At the same time, teachers are increasingly confronted with expectations to engage with AI as part of their professional practice.

The present study was conducted in Bavaria, Germany, where the integration of generative AI into schools is shaped by specific institutional conditions. Teachers are legally required to participate in continuing professional development as part of their professional duties. According to Bavarian regulations, this obligation is generally considered fulfilled by completing the equivalent of twelve days of professional development within a four-year period, with at least one third undertaken as school-based professional development (Bavarian State Ministry of Education and Cultural Affairs, 2002, 2024). However, participation in professional development specifically focused on artificial intelligence is currently not mandatory for primary school teachers. Furthermore, the implementation of GenAI in Bavarian schools is guided by strict data-protection requirements and state-level regulations based on the General Data Protection Regulation (GDPR), contributing to a cautious introduction of AI technologies into educational practice. Consequently, primary school teachers are expected to engage with emerging AI technologies while navigating a regulatory environment that emphasizes data security and responsible use. These contextual conditions may shape teachers' perceptions of risk, trust in GenAI, and perceived professional development needs and should therefore be considered when interpreting the findings of the present study.

Despite the growing body of research on artificial intelligence in education, important gaps remain regarding primary school teachers' engagement with GenAI. Existing studies have largely focused on pre-service teachers (e.g., Sanusi et al., 2024; Zhang et al., 2023) or higher education contexts (e.g., Delcker et al., 2024; Hoya et al., 2024), while the specific perspectives and professional demands of primary education have received considerably less attention. In particular, there is limited empirical evidence on how primary school teachers perceive the risks associated with GenAI, how much they trust these technologies, and which professional development needs they identify. Moreover, little is known about how these dimensions relate to one another and how they are linked to teachers' current and intended use of GenAI in educational practice.

Addressing these gaps is important for both research and practice. From a research perspective, a more differentiated understanding of teachers' perceptions may contribute to explaining why AI adoption remains uneven across educational contexts. From a practical perspective, insights into teachers' perceptions and professional development needs can inform the design of targeted support measures and professional learning opportunities.

Therefore, the present study investigates primary school teachers' perceptions of generative AI, focusing on perceived risks, trust in AI, and professional development needs. Furthermore, it examines how these dimensions are interrelated, whether distinct profiles of AI engagement can be identified, and how these profiles differ regarding current and intended use of GenAI.

To address these aims, the study is guided by the following research questions:

RQ1: How do primary school teachers perceive (risks, trust, professional development needs) and use generative AI in educational contexts?

RQ2: How are perceived risks, trust in AI, and professional development needs related to each other?

RQ3: Can distinct teacher profiles be identified based on their perceptions of generative AI, and how can these profiles be characterized?

RQ4: How do teacher profiles differ regarding their current and intended use of generative AI?

By identifying distinct teacher profiles, the study contributes to a more differentiated understanding of primary school teachers' engagement with generative AI.

2. Theoretical and Empirical Background

2.1. Adoption of AI in Educational Contexts

To understand how teachers engage with generative artificial intelligence (GenAI), it is useful to draw on established models of technology adoption and educational innovation. While AI introduces new opportunities for teaching and learning, research consistently shows that the availability of a technology alone does not guarantee its meaningful integration into educational practice. Instead, adoption depends on how teachers evaluate, understand, and translate technological possibilities into pedagogically meaningful action.

One of the most influential frameworks for explaining technology adoption is the Technology Acceptance Model (TAM; Davis, 1989; Venkatesh & Davis, 2000). According to TAM, individuals' intentions to use a technology are primarily shaped by their perceptions of its usefulness and ease of use. These perceptions influence behavioral intentions, which in turn predict actual use. In educational contexts, TAM has been widely applied to explain teachers' acceptance of digital technologies, including recent research on artificial intelligence (Chocarro et al., 2023; Ma & Lei, 2024). However, studies consistently indicate that positive attitudes and intentions do not necessarily translate into classroom implementation.

This discrepancy between intention and practice has been highlighted in research on educational technology integration for several decades. Ertmer (1999) distinguishes between first-order barriers, such as insufficient access to technology, time constraints, or lack of resources, and second-order barriers, including teachers' beliefs, professional identities, and pedagogical orientations. Even when technological infrastructure is available, these internal factors may hinder implementation. Similarly, Hew and Brush (2007) emphasize that technology integration is shaped by the interaction of individual, organizational, and contextual conditions. Consequently, favorable attitudes toward a technology do not automatically result in its classroom use.

A complementary perspective is provided by the Will–Skill–Tool (WST) model of technology integration (Knezek et al., 2000). The model proposes that technology adoption depends on three interrelated components: teachers' willingness to use a technology (*will*), their competencies and knowledge required for effective use (*skill*), and their access to technological resources and infrastructure (*tool*). From this perspective, behavioral intentions alone are insufficient to explain actual technology use. Successful integration requires that motivation and positive attitudes are supported by both adequate competencies and enabling conditions.

The skill dimension appears particularly relevant in the context of artificial intelligence. Although AI tools are becoming increasingly accessible, their pedagogically meaningful use requires more than technical familiarity. Teachers must be able to evaluate AI-generated outputs, understand the limitations of AI systems, and consider their pedagogical and ethical implications. In this regard, the concept of AI literacy has emerged as a useful framework for describing the competencies needed for responsible engagement with AI. AI literacy encompasses not only technical knowledge about AI systems but also the ability to critically assess their functioning, limitations, societal consequences, and educational implications (Long & Magerko, 2020; UNESCO, 2024). Recent reviews further suggest that teacher education and professional development often focus on technological

aspects of AI, while pedagogical, ethical, and reflective dimensions remain comparatively underrepresented (Sperling et al., 2024; Tan et al., 2025).

Professional development therefore plays a crucial role in supporting teachers' engagement with AI (UNESCO, 2019, 2023). Recent studies indicate that many teachers perceive a gap between the rapid development of AI technologies and their own preparedness to use them effectively (Li et al., 2025; Tan et al., 2025). Importantly, professional development needs should not be understood solely as indicators of lacking competence. Rather, they may also reflect teachers' awareness of emerging demands and their willingness to further develop their professional expertise in response to technological change.

Taken together, the Technology Acceptance Model and the Will-Skill-Tool framework suggest that teachers' engagement with AI depends not only on intentions to use technology but also on the factors that shape teachers' willingness and preparedness to engage with it. Within the Will-Skill-Tool framework, the dimensions of *will* and *skill* appear particularly relevant for understanding teachers' orientations toward generative AI. Teachers' willingness to engage with AI is likely influenced by how they evaluate its opportunities and risks and by the extent to which they trust AI-supported systems. At the same time, meaningful integration requires competencies that many teachers may still perceive as developing, which is reflected in their professional development needs. Accordingly, the present study focuses on three dimensions that can be theoretically linked to the Will-Skill-Tool framework: perceived risks, trust in AI, and professional development needs. These dimensions are examined in greater detail in the following section.

2.2. Teachers' Evaluations of AI: Risk, Trust and Professional Development Needs

Building on this perspective, the following section examines perceived risks, trust in AI, and professional development needs as central dimensions of teachers' engagement with generative AI. Together, these dimensions capture how teachers evaluate the opportunities and challenges associated with AI and how prepared they feel to engage with it professionally. In the context of generative artificial intelligence, teachers are required to make professional judgments under conditions of uncertainty, balancing potential benefits against possible risks while considering their own preparedness for implementation. Trust is commonly understood as the willingness to accept vulnerability and act under conditions of uncertainty (Deutsch, 1962; Hosmer, 1995; Luhmann, 1979; Mayer et al., 1995). Across these perspectives, trust involves making decisions despite incomplete information and the possibility of negative outcomes. In educational contexts, trust in AI refers to teachers' willingness to rely on AI-supported systems despite uncertainty regarding how these systems operate and the consequences their use may have for teaching and learning. Similar to research on trust in automation, trust can be understood as a mechanism that regulates whether individuals rely on, reject, or appropriately calibrate their use of technological systems (Lee & See, 2004). In educational contexts, this implies that trust may influence not only whether teachers use AI, but also how critically and responsibly they engage with it. Recent research conceptualizes teachers' trust in AI not as a general openness toward technology, but as a context-dependent professional judgment influenced by perceptions of usefulness, reliability, transparency, understanding of AI systems, and AI-related self-efficacy (Lucas et al., 2024; Nazaretsky et al., 2022; Viberg et al., 2025). Accordingly, Viberg et al. (2025) define trust in AI-supported educational technologies as teachers' willingness to accept uncertainty when integrating AI into educational practice.

Closely related to trust is the concept of perceived risk. Perceived risks refer to teachers' subjective expectations that the use of AI may lead to negative consequences for teaching, learning, or professional responsibility (Featherman & Pavlou, 2003). In educational settings, these concerns include issues such as data privacy, algorithmic bias,

inaccurate or misleading outputs, overreliance on AI-generated content, reduced student agency, and the potential loss of pedagogical control (Holmes et al., 2019). Rather than representing independent constructs, trust and perceived risks appear to form a closely interconnected evaluative framework through which teachers weigh opportunities against concerns and uncertainties (Viberg et al., 2025).

Research suggests that teachers' evaluations of AI are often characterized by ambivalence. On the one hand, many teachers recognize the potential of AI to support teaching and learning and consider AI-related competencies increasingly relevant for the future of education. On the other hand, they frequently express concerns regarding ethical implications, reliability, bias, and the consequences of AI for professional autonomy (Kohnke et al., 2025; Martin et al., 2024; OECD, 2025; Polak et al., 2022). Systematic reviews focusing on primary education describe this situation as one of cautious openness, in which perceived opportunities coexist with uncertainty and limited practical experience (Arranz-García et al., 2025; Nuryani et al., 2026).

Existing evidence further indicates that teachers often feel insufficiently prepared to engage with AI. Studies show that teachers frequently report limited knowledge about how AI systems operate and how AI should be addressed in educational contexts (Lindner & Romeike, 2019; Polak et al., 2022). Similar findings have been reported specifically for primary school teachers (Kim & Kwon, 2023). Research on pre-service and in-service teachers additionally suggests that attitudes toward AI may vary according to individual characteristics such as gender, prior experience, and confidence in using technology (Bolívar-Cruz & Verano-Tacoronte, 2025; Zhang et al., 2023). Given that primary school teaching is a predominantly female profession in many countries, these findings may be particularly relevant for understanding teachers' engagement with AI in primary education. These considerations are particularly important in primary education, where teachers support children's foundational learning, mediate emerging technologies in age-appropriate ways, and bear particular responsibility for protecting learners' privacy, autonomy, and well-being (Arranz-García et al., 2025; Nuryani et al., 2026; UNESCO, 2024).

The relationship between trust and perceived risk has also been demonstrated empirically. Zhang et al. (2025), for example, found that perceived risks negatively predict teachers' trust in AI and reduce their willingness to adopt AI-supported technologies. Conversely, transparency and explainability appear to strengthen trust and mitigate concerns. Teachers tend to place greater trust in AI when they understand how systems generate recommendations and perceive AI as supporting rather than replacing their professional expertise (Nazaretsky et al., 2022; Feldman-Maggor et al., 2025). Explainability therefore appears to be a key condition for fostering appropriate trust in AI-supported educational technologies.

A third important dimension concerns teachers' professional development needs. Professional development needs capture teachers' perceived requirement for knowledge, competencies, and support in order to use AI effectively, critically, and responsibly. In line with the Will-Skill-Tool framework discussed above, PD needs can be understood as reflecting teachers' awareness of a gap between current competencies and emerging professional demands. Importantly, PD needs do not necessarily indicate low competence. Rather, they may represent an active orientation toward learning and professional growth.

Recent studies consistently report substantial professional development needs related to AI. Teachers frequently express a desire for further training, particularly regarding pedagogical applications, ethical implications, and the critical evaluation of AI systems (Nazaretsky et al., 2022; Robert Bosch Stiftung, 2025; Sperling et al., 2024). Research also suggests that many teachers perceive existing professional development opportunities as insufficient to address the complexity of AI integration (Kohnke et al., 2025). Furthermore,

professional development appears closely linked to trust and confidence. By increasing teachers' understanding of AI systems, professional learning opportunities may reduce uncertainty and support the development of informed trust (Celik et al., 2025; Lucas et al., 2024; Nazaretsky et al., 2022).

Taken together, perceived risks, trust, and professional development needs represent central dimensions that have been used to describe teachers' engagement with AI. Whereas perceived risks and trust reflect how teachers assess the opportunities and challenges associated with AI, professional development needs indicate how prepared they feel to respond to these challenges. Although these dimensions have often been examined separately, relatively little is known about how they jointly structure teachers' orientations toward generative AI, particularly in primary education. Examining teachers' overall evaluations of these dimensions simultaneously may therefore provide a more differentiated understanding of teachers' engagement with AI and reveal distinct patterns that remain hidden in variable-centered approaches.

2.3. Heterogeneity of Teachers and Emerging Profiles

Given the complexity of AI integration, it is unlikely that teachers form a homogeneous group in their perceptions and use of AI. Research on innovation adoption suggests that individuals differ systematically in their openness to new technologies, leading to distinct patterns of adoption and engagement (Rogers, 1983). In educational contexts, teachers' responses to technological innovations are shaped not only by perceptions of usefulness but also by beliefs, professional values, prior experiences, and contextual conditions (Ertmer, 1999; Hew & Brush, 2007).

In the case of generative AI, this heterogeneity may be particularly pronounced. AI systems do not merely introduce new tools but also raise questions about professional autonomy, pedagogical responsibility, transparency, and ethical decision-making (Holmes et al., 2019). Consequently, teachers may combine perceptions of risk, trust, and professional development needs in different ways. For example, some teachers may express high levels of trust and strong interest in further learning, whereas others may perceive substantial risks and remain reluctant to engage with AI. Still others may simultaneously recognize both opportunities and challenges, resulting in more ambivalent orientations toward the technology.

Research has shown considerable variation in teachers' perceptions of AI, suggesting that teachers may differ not only in the degree but also in the combination of perceived risks, trust, and professional development needs. However, little is known about whether recurring patterns of these perceptions can be identified among primary school teachers. Examining such patterns may contribute to a more nuanced understanding of teachers' engagement with generative AI and inform the development of targeted professional development opportunities.

2.4. Summary and Conceptual Framework

Taken together, the reviewed literature suggests that teachers' engagement with generative AI can be described by a complex interplay of adoption-related factors, evaluations of risks and trust, and perceived professional development needs. Although previous studies have provided valuable insights into these dimensions, research in primary education remains limited and has predominantly relied on variable-centered approaches. As a result, little is known about whether distinct patterns of AI-related perceptions exist among primary school teachers and how such patterns are associated with current and intended AI use. Addressing this gap, the present study adopts a person-centered perspective to identify distinct profiles of primary school teachers based on perceived risks, trust in AI,

and professional development needs and to examine how these profiles differ in current and intended AI use. In the present study, engagement with generative AI is understood as teachers' overall orientation toward AI, reflected in their evaluations of perceived risks, trust in AI, professional development needs, as well as their reported current and intended use of AI in educational practice.

3. Methods

3.1. Sample and Procedure

The study is based on a quantitative survey of primary school teachers in Bavaria (Germany), conducted during the 2023/2024 school year. A total of N = 295 teachers participated in the study. The sample consisted predominantly of female teachers (93%), with an average teaching experience of 18.6 years (SD = 10.5).

Missing data accounted for 2.6% of the total dataset. To assess the robustness of the subsequent analyses, missingness patterns were examined using a combination of visual inspection (naniar package; Tierney & Cook, 2023) and Little's MCAR test (Little, 1988). The visual analysis revealed no systematic patterns, and Little's test was non-significant ($p > 0.05$), supporting the assumption that the data were missing completely at random (MCAR). Given the low proportion of missing values and the assumption of MCAR, listwise deletion was applied. This approach is considered appropriate under MCAR conditions and minimizes the risk of biased estimates (Graham, 2009; Little & Rubin, 2019).

3.2. Measures

Participants responded to three items assessing perceived risks, trust in AI, and professional development (PD) needs:

(1) "When using ChatGPT or similar AI tools in school, I see more risks than opportunities."
(2) "I trust tools such as ChatGPT or similar AI applications for use in school."
(3) "I would like to receive professional development to learn more about the use of ChatGPT or similar AI tools in school."

All items were measured on a six-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree).

The present study did not aim to provide comprehensive psychometric assessments of perceived risks, trust in AI, or professional development needs. Rather, these variables were operationalized as global evaluative indicators reflecting teachers' overall orientations toward generative AI and served as the basis for the person-centered profile analysis. The use of single-item indicators was intended to capture these overall evaluations rather than the differentiated facets of the multidimensional constructs discussed in Section 2.2. Recent methodological research suggests that the usefulness of single-item measures depends on the nature of the construct, the wording of the item, and the intended interpretation of the resulting scores (Allen et al., 2022; Matthews et al., 2022). Consequently, the present indicators should be interpreted as global evaluations rather than comprehensive measures of trust, perceived risk, or professional development needs. This operationalization is consistent with the person-centered objective of the study, which aimed to identify broad patterns of teachers' overall orientations toward generative AI rather than to model latent psychological constructs or examine relationships among multidimensional scales. In addition, participants reported their current and intended use of generative AI across different instructional and classroom-related activities. Instructional use was assessed using seven items covering activities such as lesson planning, preparation of instructional materials, and content-related support. Classroom integration was assessed using two items referring to the use of AI in teaching and student-related activities.

Based on these items, four indices were computed as the mean of the respective items:

(a) Current instructional use;
(b) Intended instructional use;
(c) Current classroom integration;
(d) Intended classroom integration.

Higher values indicate more frequent use or stronger intentions to use generative AI.

The instructional use indices showed good to excellent internal consistency (current use: $\alpha = 0.87$; intended use: $\alpha = 0.93$). For classroom integration, the two-item indices showed inter-item correlations of $r = 0.55$ for current use and $r = 0.80$ for intended use, with corresponding Spearman–Brown coefficients of 0.71 and 0.89, respectively.

3.3. Data Analysis

Data analyses were conducted using R (Version 4.3.0; R Foundation for Statistical Computing, Vienna, Austria; R Core Team, 2023).

First, descriptive statistics (means, standard deviations, and frequencies) were calculated to examine teachers' perceptions of risks, trust, professional development needs, and AI use (RQ1). Pearson correlation coefficients were computed to investigate the relationships between perceived risks, trust, and PD needs (RQ2).

Second, a person-centered approach was employed to identify distinct profiles of AI engagement (RQ3). Person-centered approaches are particularly suitable when the objective is to identify naturally occurring configurations of variables rather than to estimate relations among latent constructs (Woo et al., 2024). A two-step clustering procedure was applied. In the first step, hierarchical cluster analysis using Ward's method and squared Euclidean distances was conducted to examine the cluster structure based on the dendrogram and elbow criterion. In the second step, competing k-means solutions with two to four clusters were compared. Average silhouette widths were 0.353, 0.297, and 0.321 for the two-, three-, and four-cluster solutions, respectively. Considering the initial cluster diagnostics together with parsimony and substantive interpretability, the three-cluster solution was retained. In particular, it distinguished a group characterized by comparatively high perceived risks and professional development needs alongside moderate trust, whereas this pattern was merged in the two-cluster solution and the four-cluster solution primarily further differentiated the more skeptical and trusting configurations. Agreement between the hierarchical and final k-means assignments for the three-cluster solution was limited (adjusted Rand index = 0.260), indicating some sensitivity of individual assignments to the clustering method. Prior to analysis, all clustering variables were standardized (z-scores).

Third, reliability analyses were conducted for the multi-item indices. Cronbach's alpha was calculated for instructional use. For the two-item classroom integration indices, inter-item correlations and Spearman–Brown coefficients were reported.

Finally, one-way analyses of variance (ANOVA) were performed to examine differences between the identified teacher profiles regarding current and intended AI use (RQ4). Tukey's HSD post hoc tests were used to identify specific group differences. Effect sizes were calculated using eta-squared (η^2).

4. Results

4.1. Teachers' Perceptions and Use of Generative AI (RQ1)

Teachers reported mixed perceptions of generative AI, characterized by moderate levels of perceived risk, relatively low trust, and substantial professional development needs (Table 1). Perceived risks were slightly above the scale midpoint, indicating a tendency toward cautious skepticism rather than strong rejection. In contrast, trust in AI was comparatively low, suggesting a generally cautious evaluation of AI tools in educational contexts.

At the same time, teachers expressed considerable interest in professional development related to the educational use of AI.

Table 1. Descriptive statistics for Perceived Risks, Trust in AI, Professional Development Needs, and AI Use variables.

Variable	*N*	*M*	*SD*	Median	Min	Max
Perceived Risks	294	3.75	1.22	4	1	6
Trust in AI	292	2.73	1.08	3	1	6
Professional Development Needs	294	4.12	1.41	4	1	6
Current Instructional Use	290	1.37	0.63	1	1	4
Intended Instructional Use	291	2.57	1.14	3	1	6
Current Classroom Integration	290	1.22	0.55	1	1	5
Intended Classroom Integration	290	2.36	1.12	2	1	6

Descriptive analyses of teachers' use of generative AI further revealed a clear gap between current practices and intended use (Table 1). Current use of AI for instructional purposes was very low, with the majority of teachers indicating that they rarely or never use AI in their teaching. Similarly, classroom integration of AI, such as discussing AI in class or incorporating it into student tasks, was minimal.

In contrast, teachers reported substantially higher levels of intended use. Intended use for instructional purposes reached a moderate level, and intentions to integrate AI into classroom activities were also noticeably higher than current levels of implementation. Taken together, these findings suggest that teachers are currently engaging with AI only to a limited extent, despite expressing greater openness toward future use.

4.2. Relationships Between Perceived Risks, Trust, and Professional Development Needs (RQ2)

Correlation analyses revealed a structured pattern of teachers' perceptions of AI (Table 2). Perceived risks were strongly negatively associated with trust in AI, indicating that teachers who perceived higher levels of risk tended to report lower levels of trust. This finding suggests that both constructs represent closely related dimensions of teachers' evaluations of AI. However, the magnitude of this association should be interpreted with some caution, as the comparative wording of the risk item ("more risks than opportunities") may partly contribute to its conceptual overlap with the global evaluation captured by the trust item.

Table 2. Correlations among perceived risks, trust in AI, and professional development needs.

Variable	1	2	3
1. Perceived Risks	1.00		
2. Trust in AI	−0.60 ***	1.00	
3. Professional Development Needs	−0.28 ***	0.33 ***	1.00

Note. Pearson correlations. *** $p < 0.001$.

Trust in AI was positively associated with professional development needs, suggesting that teachers who expressed greater trust in AI were also more interested in further learning opportunities. In contrast, perceived risks were negatively related to professional development needs, indicating that teachers who were more skeptical toward AI tended to express less interest in professional development. Overall, the findings suggest that perceived risks, trust, and professional development needs form a coherent pattern of attitudes toward AI.

4.3. Cluster Analysis (RQ3)

To identify distinct patterns of AI engagement, a cluster analysis based on perceived risks, trust in AI, and professional development needs was conducted. A three-cluster solution was selected as the most interpretable representation of teachers' perceptions (Table 3).

Table 3. Cluster means and sample sizes for the identified teacher profiles.

Profile	*n* (%)	Perceived Risks (*M*)	Trust in AI (*M*)	Professional Development Needs (*M*)
Skeptical Rejecters	73 (25.0%)	4.96	1.62	2.58
Interested but Uncertain	131 (44.9%)	3.91	2.64	4.92
Trusting Learners	88 (30.1%)	2.53	3.80	4.20

Note. Cluster membership was determined using k-means clustering based on standardized scores of perceived risks, trust in AI, and professional development needs. Percentages are based on the cluster-analytic sample (n = 292).

The first cluster, labeled Skeptical Rejecters, was characterized by very high perceived risks, very low trust in AI, and comparatively low interest in professional development.

The second cluster, labeled Interested but Uncertain, combined relatively high perceived risks and low trust with the strongest interest in professional development. This profile represented the largest group of teachers and was characterized by this specific combination of scores across the three global indicators.

The third cluster, labeled Trusting Learners, showed comparatively low perceived risks, higher levels of trust, and substantial interest in professional development.

Taken together, the findings indicate that primary school teachers do not form a homogeneous group in their perceptions of AI but can be differentiated into distinct profiles characterized by different combinations of risk perceptions, trust, and professional development needs. The profile labels are descriptive shorthand for the specific patterns identified across the three global evaluative indicators and should not be interpreted as representing comprehensive psychological constructs or diagnostic categories.

An additional comparison among teachers with available data on teaching experience (n = 269) revealed a small difference across profiles, $F(2, 266) = 4.03$, $p = 0.019$, $\eta^2 = 0.03$. Tukey post hoc comparisons indicated that Skeptical Rejecters reported more teaching experience (M = 21.35, SD = 9.82) than Trusting Learners (M = 16.41, SD = 11.25; $p = 0.014$), whereas the other pairwise differences were not significant.

4.4. Group Differences in AI Use (RQ4)

To examine whether the identified profiles differed in their engagement with AI, a series of one-way analyses of variance (ANOVA) was conducted (Table 4).

Table 4. ANOVA results and descriptive statistics for differences between teacher profiles in current and intended AI use.

Variable	Skeptical Rejecters *M* (*SD*)	Interested but Uncertain *M* (*SD*)	Trusting Learners *M* (*SD*)	*F*	*df*	*p*	η^2
Current Instructional Use	1.12 (0.30)	1.28 (0.55)	1.71 (0.79)	22.66	(2, 285)	<0.001	0.14
Intended Instructional Use	1.76 (0.89)	2.66 (1.02)	3.14 (1.13)	36.73	(2, 286)	<0.001	0.20
Current Classroom Integration	1.05 (0.19)	1.19 (0.50)	1.40 (0.75)	8.68	(2, 285)	<0.001	0.06
Intended Classroom Integration	1.78 (0.91)	2.45 (1.07)	2.73 (1.19)	16.13	(2, 285)	<0.001	0.10

Note. Values for the three profiles are means with standard deviations in parentheses. One-way analyses of variance (ANOVA) were conducted with teacher profile as the independent variable. Effect sizes are reported as eta-squared (η^2).

Significant differences emerged for both current and intended use of generative AI. For current instructional use, profile membership had a significant effect. Post hoc comparisons indicated that Trusting Learners reported significantly higher levels of current instructional use than both Interested but Uncertain teachers and Skeptical Rejecters, whereas the latter two groups did not differ significantly from one another.

Profile differences were even more pronounced for intended instructional use, suggesting that teachers' perceptions of AI are particularly relevant for their readiness to engage with the technology in the future. Similar patterns emerged for classroom integration. Significant differences were observed for both current classroom integration and intended future classroom integration, with Trusting Learners generally reporting higher levels of engagement than the other groups.

Overall, the findings demonstrate that the identified teacher profiles differ not only in their perceptions of generative AI but also in their current practices and future intentions. While actual use remains comparatively limited across all groups, more positive profiles are associated with stronger intentions to integrate AI into educational practice in the future.

5. Discussion

5.1. Teachers' Perceptions in Context: A State of Cautious Openness

The findings provide a snapshot of primary school teachers' engagement with generative AI during an early phase of its adoption, characterized by a state of cautious openness. Teachers reported moderate to high perceived risks, relatively low trust in AI, and substantial professional development needs. At the same time, they did not reject AI outright and expressed considerable interest in further learning opportunities related to its educational use. This combination suggests that teachers are currently balancing the perceived opportunities and risks associated with AI rather than adopting clearly positive or negative positions. This may be particularly characteristic of primary education, where teachers are responsible not only for subject learning but also for children's cognitive, social, and moral development (Kantreiter et al., 2024) and therefore face especially demanding pedagogical decisions regarding the use of emerging technologies. The institutional context in Bavaria may help explain this pattern. As outlined in the introduction, primary school teachers operate within a regulatory environment characterized by strict data-protection requirements and, at the same time, currently no mandatory professional development specifically focused on artificial intelligence. These contextual conditions may partly explain the combination of cautious attitudes, comparatively low trust, and substantial professional development needs observed in the present study.

The findings align with recent research indicating that teachers often hold ambivalent attitudes toward AI. While many educators recognize the potential of AI to support teaching and learning, they simultaneously express concerns regarding reliability, bias, data protection, ethical implications, and the consequences of AI for professional autonomy (Kohnke et al., 2025; Martin et al., 2024; OECD, 2025; Polak et al., 2022). Similar patterns have been reported in reviews focusing on primary education, where teachers are described as cautiously interested in AI while remaining uncertain about its educational implications (Arranz-García et al., 2025; Nuryani et al., 2026).

Particularly noteworthy is the comparatively low level of trust observed in the present study. Trust has repeatedly been identified as a key prerequisite for the adoption of AI-supported technologies in educational settings (Nazaretsky et al., 2022; Viberg et al., 2025). The findings suggest that many primary school teachers remain hesitant to rely on AI systems, which may reflect uncertainty regarding the reliability, transparency, and pedagogical appropriateness of AI-generated outputs. Given that primary school teachers are responsible for establishing foundational literacy, numeracy, and learning strategies,

while simultaneously fostering children's social, emotional, and moral development, such caution appears understandable.

The observed relationship between the global indicator of perceived risks and trust further supports previous research suggesting that these evaluations are closely related in teachers' overall orientations toward AI (Nazaretsky et al., 2022; Viberg et al., 2025). Teachers who perceived higher levels of risk tended to report lower levels of trust, highlighting the importance of addressing concerns related to transparency, reliability, and ethical use when promoting AI adoption in schools.

A second notable finding concerns teachers' substantial professional development needs. Consistent with previous studies (Nazaretsky et al., 2022; Robert Bosch Stiftung, 2025; Sperling et al., 2024), participants expressed a strong desire for further learning opportunities related to AI. This finding is particularly relevant given the rapid pace of technological development and the increasing expectation that teachers engage with AI in professionally responsible ways. The reported global indicator of professional development needs should not be interpreted solely as indicators of insufficient competence. Rather, they may reflect teachers' awareness of emerging professional demands and their willingness to further develop their expertise. In this sense, the reported need for professional development may be interpreted as a constructive response to educational change rather than as evidence of a deficit.

Taken together, the findings portray primary school teachers as neither enthusiastic adopters nor categorical opponents of AI. Instead, their responses suggest a balanced and reflective stance characterized by awareness of both opportunities and challenges. This state of cautious openness provides an important context for understanding the distinct teacher profiles identified in the present study.

5.2. Distinct Profiles of AI Engagement

The identification of three distinct teacher profiles—Skeptical Rejecters, Interested but Uncertain, and Trusting Learners—provides empirical support for the assumption that teachers do not form a homogeneous group in their engagement with AI (Rogers, 1983). By adopting a person-centered approach, the present study extends existing research by identifying distinct profiles of teachers and linking these profiles to both current and intended AI use. The findings demonstrate that teachers differ considerably in how they combine perceptions of risk, trust, and professional development needs, highlighting the value of moving beyond average scores when examining teachers' engagement with emerging technologies.

The Skeptical Rejecters profile is characterized by high perceived risks, low trust, and low interest in professional development. This pattern may reflect a relatively stable skeptical stance toward AI that may be rooted in fundamental concerns about its compatibility with pedagogical values and the role of the teacher (Holmes et al., 2019). In contrast, the Trusting Learners profile combines comparatively low perceived risks with higher levels of trust and a strong interest in professional development, indicating a greater willingness to engage with AI and explore its educational potential.

Particularly noteworthy is the profile of Interested but Uncertain teachers, which represented the largest group in the sample (44.9%). Interestingly, this combination highlights the limitation of purely variable-centered approaches: while the global correlation analysis indicated that higher perceived risk is linearly associated with lower professional development needs, this substantial sub-population demonstrates a more nuanced, non-linear pattern. This discrepancy underscores the methodological value of the person-centered cluster analysis employed in this study, as it reveals critical configurations of attitudes that remain hidden in aggregate correlations. Rather than reflecting resistance, the In-

terested but Uncertain profile may be interpreted as a state of productive uncertainty, in which teachers are open to engaging with AI but require further support and orientation to translate this openness into practice. This finding suggests that uncertainty does not necessarily function as a barrier to engagement. Instead, it may motivate teachers to seek further knowledge and professional support in order to make informed decisions about the educational use of AI.

Across all three profiles, a noteworthy pattern emerges. Even teachers who express comparatively positive attitudes toward AI report very limited actual classroom use. One possible interpretation of this finding is what we propose as a *pedagogical brake*: a theoretical concept describing the tendency for teachers to approach the implementation of generative AI with particular caution in primary education. From this perspective, openness toward AI does not necessarily translate directly into classroom implementation. Instead, teachers may carefully weigh potential pedagogical benefits against concerns related to developmental appropriateness, professional responsibility, and ethical implications. Especially in primary education, where teachers are responsible for supporting foundational learning processes and protecting particularly vulnerable learners, such caution may represent a professionally reasoned response rather than resistance to innovation (Ertmer, 1999; Hew & Brush, 2007; Nuryani et al., 2026). However, the present data do not allow us to determine whether limited classroom use actually results from deliberate pedagogical considerations. The proposed *pedagogical brake* should therefore be understood as a tentative theoretical interpretation that requires further empirical investigation.

From this perspective, the identified profiles should not be interpreted as positions on a simple continuum from rejection to acceptance. Instead, they reflect different ways in which teachers balance the perceived opportunities and risks associated with AI. The profile of the Interested but Uncertain teachers is particularly illustrative of this tension, combining substantial concerns with the strongest demand for professional development.

Taken together, the identified profiles suggest that teachers' engagement with AI is shaped not only by perceptions of technological usefulness but also by broader considerations of professional responsibility, uncertainty, and learning. The findings further highlight that teachers respond differently to emerging technologies and may therefore require different forms of support. Consequently, one-size-fits-all approaches to professional development are unlikely to meet the needs of all teachers equally.

The identified profiles are also consistent with a growing body of person-centered research suggesting that engagement with generative AI is characterized by heterogeneous user groups rather than homogeneous patterns. For example, Beckman et al. (2025) identified distinct profiles of university students that differed in AI literacy, confidence, and patterns of GenAI use. Although AI literacy was not assessed in the present study, these findings suggest that differences in AI-related competencies may also contribute to the teacher profiles identified here. This interpretation is further supported by the systematic review of Bewersdorff et al. (2025), which found consistent positive associations between AI literacy, AI self-efficacy, positive attitudes toward AI, and broader digital competencies. Future research should therefore examine whether AI literacy contributes to the emergence of different teacher engagement profiles among primary school teachers.

5.3. Patterns of Use and the Intention-Usage Gap

The identified teacher profiles differed not only in their perceptions of generative AI but also in their current practices and intended use. Profile differences were more pronounced for intended than for current AI use, indicating that intentions may differentiate teacher profiles more strongly than current implementation practices. This pattern aligns with the Technology Acceptance Model (TAM), which assumes that perceptions primarily

influence behavioral intentions, while actual use is often moderated by contextual and organizational factors (Davis, 1989; Venkatesh & Davis, 2000).

This finding is also consistent with the Will–Skill–Tool model (Knezek et al., 2000), which argues that willingness alone does not necessarily lead to technology integration. The high professional development needs identified in the present study suggest that teachers perceive a need to further develop the competencies associated with the "skill" component, while the limited classroom use across all profiles may also reflect constraints related to contextual conditions and implementation opportunities represented by the "tool" component.

The descriptive pattern of higher intended than current use across all profiles is consistent with an intention–usage gap. Although teachers differed considerably in their perceptions of AI, actual classroom use remained low even among the more positive profiles, while intentions for future use were substantially higher. This pattern resembles the well-documented intention–usage gap reported in technology adoption research (Ertmer, 1999; Hew & Brush, 2007). However, the present data do not allow us to determine whether this gap is indeed driven by pedagogical considerations.

The present study extends this line of research by showing that this gap persists even among teachers with relatively positive evaluations of AI. In particular, the Trusting Learners profile demonstrates that more favorable overall evaluations of perceived risks, trust in AI, and professional development needs do not automatically translate into classroom implementation. More favorable overall evaluations therefore appear to be a necessary but insufficient condition for the educational use of AI. This finding closely aligns with the Will-Skill-Tool model (Knezek et al., 2000), which argues that willingness alone does not lead to technology integration. Instead, teachers also require sufficient competencies and supportive contextual conditions. The high professional development needs identified in the present study point to the continuing importance of the "skill" component, while the limited classroom use across all profiles suggests that contextual factors and available implementation opportunities ("tool") may continue to constrain AI adoption.

Several factors may contribute to this discrepancy between intention and use. Previous research highlights the importance of professional learning opportunities, institutional support, technological infrastructure, and pedagogical guidance when integrating new technologies into educational practice (Celik et al., 2025; Collie et al., 2024; Hew & Brush, 2007). In addition, teachers may remain uncertain about the pedagogical appropriateness of AI use, particularly in primary education, where developmental considerations and ethical responsibilities are especially salient.

Taken together, the findings suggest that primary education is currently experiencing a transitional phase in AI adoption. Teachers' overall evaluations and intentions appear to be changing more rapidly than their classroom practices. Consequently, future research and professional development efforts should not only focus on fostering positive perceptions of AI but also on addressing the practical, pedagogical, and organizational conditions necessary for its responsible implementation.

5.4. Implications for Professional Development

The findings have important implications for the design of teacher professional development in the context of artificial intelligence. First, the overall high demand for professional development confirms a persistent gap between the rapid development of AI technologies and teachers' perceived preparedness to use them effectively and responsibly. This finding is consistent with previous research indicating that many teachers feel insufficiently equipped to address the pedagogical, ethical, and practical challenges associated

with AI integration (Nazaretsky et al., 2022; Robert Bosch Stiftung, 2025; Sperling et al., 2024; Tan et al., 2025).

Second, the identification of distinct teacher profiles suggests that one-size-fits-all approaches to AI-related professional development are unlikely to be effective. Teachers differ substantially in their perceptions of risks, trust, and professional learning needs, indicating that different groups may require different forms of support.

For Trusting Learners, professional development may focus on advanced pedagogical integration, including the critical evaluation of AI-generated content, the design of AI-supported learning environments, and the development of subject-specific applications. These teachers already appear willing to engage with AI and may therefore benefit most from opportunities to deepen and refine their practice.

For Interested but Uncertain teachers, the priority lies in building confidence and reducing uncertainty. Given that this group combines substantial concerns with the strongest demand for professional development, it represents a particularly promising target group for professional learning initiatives. Professional development for these teachers should provide transparent explanations of AI systems, opportunities for guided experimentation, and structured reflection on ethical and pedagogical implications. Such approaches may help transform uncertainty into informed professional judgment and responsible educational action (Nazaretsky et al., 2022; Viberg et al., 2025).

For Skeptical Rejecters, professional development may need to begin with addressing more fundamental concerns regarding the role of AI in education, child development, and pedagogical responsibility. Rather than focusing primarily on technical skills, professional learning opportunities for this group should create spaces for critical dialogue and discussion about both the opportunities and limitations of AI in educational contexts.

More broadly, the findings suggest that professional development should extend beyond the acquisition of technical competencies. In line with recent AI literacy frameworks (Long & Magerko, 2020; UNESCO, 2024), effective professional development should support teachers in developing the knowledge, critical reflection skills, and professional judgment required to evaluate whether and how AI can be used without compromising the development of foundational competencies, children's autonomy, or meaningful teacher–student interaction. Particularly in primary education, where teachers are responsible for supporting foundational learning processes and young learners' development, such reflective capacities may be as important as technological proficiency itself.

Taken together, the findings highlight that successful AI integration depends not only on access to technology but also on teachers' ability to make informed pedagogical decisions about when, how, and for what purposes AI should be used. Professional development therefore plays a central role in supporting teachers as they navigate the opportunities and challenges associated with generative AI.

5.5. Limitation and Future Research

Despite its contributions, the present study has several limitations that should be considered when interpreting the findings.

First, the study was based on a survey of primary school teachers in Bavaria, Germany. Consequently, the findings may not be fully generalizable to teachers in other educational contexts, school systems, or countries. In particular, the institutional context of Bavarian primary education—including its framework for continuing professional development and the regulatory conditions governing the implementation of generative AI—should be considered when interpreting and transferring the findings to other educational systems. In addition, participation was voluntary, which may have introduced self-selection bias. Teachers with a particular interest in AI or digital technologies may have been more likely

to participate, potentially leading to a sample that is more engaged with AI-related topics than the broader population of primary school teachers. Furthermore, the cross-sectional design does not allow conclusions about causal relationships between perceived risks, trust in AI, professional development needs, and AI use. Longitudinal studies are needed to examine how teachers' perceptions and engagement with AI evolve over time.

Second, the study relies on self-reported data. As with all survey-based research, responses may be influenced by social desirability, self-perception biases, or respondents' interpretations of the survey items. In particular, teachers' reported intentions to use AI in the future may not necessarily translate into actual classroom practices. Future studies could complement self-report measures with observational data, usage logs, or qualitative approaches to gain a more comprehensive understanding of AI-related practices.

Third, perceived risks, trust in AI, and professional development needs were operationalized using concise global indicators rather than multidimensional instruments. These indicators were intended to capture teachers' overall evaluations of these dimensions and thereby support the exploratory, person-centered objective of identifying broad teacher profiles. Consequently, the findings should be interpreted as reflecting teachers' overall evaluative orientations toward generative AI rather than comprehensive representations of the multidimensional constructs discussed in Section 2.2. The present study does not permit conclusions about the specific facets underlying these evaluations, such as usefulness, reliability, transparency, and self-efficacy in relation to trust, or privacy concerns, algorithmic bias, overreliance, and loss of pedagogical control in relation to perceived risks. Future research should therefore complement the present approach by employing multidimensional instruments to examine which components of trust, perceived risk, and professional development needs are most strongly associated with different teacher profiles and whether more differentiated measures yield similar or distinct profile solutions. In addition, all three indicators explicitly referred to "ChatGPT or similar AI tools." This framing may have directed participants' evaluations primarily toward chatbot-based generative AI and may not capture their perceptions of other AI-supported educational technologies. The findings should therefore be interpreted within this specific framing rather than generalized to teachers' evaluations of AI-supported educational technologies more broadly.

Fourth, the study focused on three central dimensions of teachers' engagement with AI but did not directly assess potentially influential contextual factors. Variables such as AI-related knowledge, prior experience with AI, institutional support, school culture, technological infrastructure, or participation in professional development may play an important role in shaping teachers' perceptions and practices. Recent research suggests that AI literacy is positively associated with AI self-efficacy, attitudes toward AI, and broader digital competencies (Bewersdorff et al., 2025). Future research should therefore integrate these factors to develop a more comprehensive understanding of AI adoption in educational settings and to examine whether differences in AI literacy contribute to the emergence of distinct teacher engagement profiles.

Finally, the cross-sectional design limits conclusions regarding causal relationships and developmental processes. In addition, the data were collected during the 2023/2024 school year. Given the rapid development of generative AI, the findings should be interpreted as reflecting teachers' perceptions at that particular stage of AI adoption. Teachers' perceptions of AI are likely to evolve as technologies become more widespread, educational policies develop, and opportunities for professional learning increase. Longitudinal studies would therefore be particularly valuable for examining how teachers' profiles, attitudes, and practices change over time and whether movement between profiles occurs as experience with AI increases.

Despite these limitations, the present study contributes to the growing body of research on AI in education by providing a differentiated, person-centered perspective on primary school teachers' engagement with generative AI. By identifying distinct profiles and linking them to patterns of use, the study offers insights that may inform both future research and the design of targeted professional development initiatives.

6. Conclusions

The present study contributes to the growing body of research on artificial intelligence in education by providing a differentiated perspective on primary school teachers' engagement with generative AI. While discussions about AI in education often emphasize either its transformative potential or its associated risks, the findings of this study suggest a more nuanced picture. Primary school teachers' perceptions of AI are characterized by cautious openness, combining awareness of potential opportunities with concerns regarding educational, ethical, and practical implications.

By adopting a person-centered approach, the study identified three distinct profiles of AI engagement—Skeptical Rejecters, Interested but Uncertain, and Trusting Learners. These profiles reveal distinct patterns of AI-related perceptions and professional learning needs among primary school teachers. Particularly noteworthy is the finding that the largest group of teachers was characterized not by rejection or uncritical acceptance, but by uncertainty accompanied by a strong desire for further learning and professional support.

The study further identified a consistent descriptive pattern in which intended AI use exceeded current classroom implementation across all profiles. This pattern is consistent with an intention–usage gap. Although teachers expressed considerable interest in future AI use, actual classroom implementation remained limited across all profiles. This finding suggests that the integration of generative AI in primary education is not merely a question of technological availability or positive attitudes. Rather, its implementation is likely to be shaped by pedagogical, ethical, and professional considerations in addition to technological availability and teachers' overall evaluations. The findings suggest that many primary school teachers are currently in a phase of professional orientation toward AI. Rather than rejecting AI or embracing it uncritically, they appear to be weighing its potential educational value against perceived risks and implications for professional practice. This interpretation is reflected particularly in the large group of Interested but Uncertain teachers, whose responses indicate openness to AI alongside a strong need for guidance and professional learning opportunities.

Taken together, the findings suggest that the responsible integration of generative AI in primary education may be supported not only by technological developments but also by opportunities for teachers to develop relevant competencies, confidence, and professional judgment. Professional development may therefore play an important role in supporting teachers' pedagogically meaningful and ethically informed engagement with AI in ways that are responsive to the needs of young learners.

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

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted with authorization from the Bavarian State Ministry of Education and Cultural Affairs. No separate ethical review was obtained. Participation was voluntary and anonymous.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and data protection restrictions.

Acknowledgments: During the preparation of this manuscript, the authors used ChatGPT (version 5.6, GPT-5.6 Sol; OpenAI) to support language editing, text revision, and the development of draft formulations. The authors reviewed and edited all outputs and take full responsibility for the content of this publication.

Conflicts of Interest: The authors declare no conflicts of interest.

References

Allen, M. S., Iliescu, D., & Greiff, S. (2022). Single-item measures in psychological science: A call to action. *European Journal of Psychological Assessment*, *38*(1), 1–5. [CrossRef]

Arranz-García, O., del Romero Garcia, M. C., & Alonso-Secades, V. (2025). Perceptions, strategies, and challenges of teachers in the integration of artificial intelligence in primary education: A systematic review. *Journal of Information Technology Education: Research*, *24*, 6. [CrossRef] [PubMed]

Bavarian State Ministry of Education and Cultural Affairs. (2002). *Lehrerfortbildung in Bayern* (KWMBl. I S. 260). Bavarian State Ministry of Education and Cultural Affairs.

Bavarian State Ministry of Education and Cultural Affairs. (2024). *Legal framework for teacher professional development*. Available online: https://www.km.bayern.de/unterrichten/fort-und-weiterbildung/rechtliche-rahmenbedindungen (accessed on 26 August 2026).

Beckman, K., Apps, T., Howell, J., & Chen, L. (2025). The GenAI divide among university students: A call for action. *Internet and Higher Education*, *67*, 101036. [CrossRef]

Bewersdorff, A., Nerdel, C., & Zhai, X. (2025). How AI literacy correlates with affective, behavioral, cognitive and contextual variables: A systematic review. *Computers and Education: Artificial Intelligence*, *10*, 100493. [CrossRef]

Bolívar-Cruz, A., & Verano-Tacoronte, D. (2025). Is anxiety affecting the adoption of ChatGPT in university teaching? A gender perspective. *Technology, Knowledge and Learning*, *30*, 2373–2392. [CrossRef]

Burns, M., Winthrop, R., Luther, N., Venetis, E., & Karim, R. (2026). *A new direction for students in an AI world: Prosper, prepare, protect*. Brookings Center for Universal Education.

Celik, I., Muukkonen, H., & Siklander, S. (2025). Teacher—Artificial Intelligence (AI) interaction: The role of trust, subjective norm and innovativeness in Teachers' acceptance of educational chatbots. *Policy Futures in Education*, *24*(1), 164–188. [CrossRef]

Chocarro, R., Cortiñas, M., & Marcos-Matás, G. (2023). Teachers' attitudes towards chatbots in education: A technology acceptance model approach considering the effect of social language, bot proactiveness, and users' characteristics. *Educational Studies*, *49*(2), 295–313. [CrossRef]

Collie, R. J., Martin, A. J., & Gasevic, D. (2024). Teachers' generative AI self-efficacy, valuing, and integration at work: Examining job resources and demands. *Computers and Education: Artificial Intelligence*, *7*, 100333. [CrossRef]

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319–340. [CrossRef] [PubMed]

Delcker, J., Heil, J., Ifenthaler, D., Seufert, S., & Spirgi, L. (2024). First-year students' AI-competence as a predictor for intended and de facto use of AI-tools for supporting learning processes in higher education. *International Journal of Educational Technology in Higher Education*, *21*, 18. [CrossRef]

Deutsch, M. (1962). Cooperation and trust: Some theoretical notes. In M. R. Jones (Ed.), *Nebraska symposium on motivation* (pp. 275–319). University of Nebraska Press.

Ertmer, P. A. (1999). Addressing first- and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development*, *47*(4), 47–61. [CrossRef]

Favero, L., Pérez-Ortiz, J. A., Käser, T., & Oliver, N. (2026). AI in education beyond learning outcomes: Cognition, agency, emotion, and ethics. *arXiv*. [CrossRef]

Featherman, M. S., & Pavlou, P. A. (2003). Predicting e-services adoption: A perceived risk facets perspective. *International Journal of Human-Computer Studies*, *59*(4), 451–474. [CrossRef]

Feldman-Maggor, Y., Cukurova, M., Kent, C., & Alexandron, G. (2025). The impact of explainable AI on teachers' trust and acceptance of AI EdTech recommendations: The power of domain-specific explanations. *International Journal of Artificial Intelligence in Education*, *35*, 2889–2922. [CrossRef]

Graham, J. W. (2009). Missing data analysis: Making it work in the real world. *Annual Review of Psychology*, *60*, 549–576. [CrossRef] [PubMed]

Harry, A., & Sayudin, S. (2023). Role of AI in education. *Interdisciplinary Journal and Humanity (INJURITY)*, *2*(3), 260–268. [CrossRef]

Heeg, D. M., & Avraamidou, L. (2023). The use of Artificial intelligence in school science: A systematic literature review. *Educational Media International*, *60*(2), 125–150. [CrossRef]

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development*, *55*(3), 223–252. [CrossRef]

Hodges, C. B., & Kirschner, P. A. (2024). Innovation of instructional design and assessment in the age of generative artificial intelligence. *TechTrends*, *68*(1), 195–199. [CrossRef]

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign.

Hosmer, L. T. (1995). Trust: The connecting link between organizational theory and philosophical ethics. *Academy of Management Review*, *20*(2), 379–403. [CrossRef]

Hoya, F., Mah, D.-K., Prilop, C. N., Jacobsen, L. J., & Weber, K. E. (2024). Pre-service teachers' AI usage: The effects of perceived usefulness, subjective norm, behavioral intention, and self-efficacy. *OSF Preprints*. [CrossRef]

Kantreiter, J., Meyer, S., Elting, C., Lenzgeiger, B., Jung, J., & Lohrmann, K. (2024). Welche Effekte hatte die COVID-19-pandemie auf grundlegende Bildungsangebote zur Lern- und Persönlichkeitsentwicklung? *Zeitschrift für Grundschulforschung*, *17*(2), 263–284. [CrossRef]

Kim, K., & Kwon, K. (2023). Exploring the AI competencies of elementary school teachers in South Korea. *Computers and Education: Artificial Intelligence*, *4*, 100137. [CrossRef]

Knezek, G., Christensen, R., Hancock, R., & Shoho, A. (2000, February 12). *Toward a structural model of technology integration*. Hawaii Educational Research Association Annual Conference, Honolulu, HI, USA.

Kohnke, L. M. A., Zou, D., Ou, A. W., & Gu, M. Y. M. (2025). Preparing future educators for AI-enhanced classrooms: Insights into AI literacy and integration. *Computers and Education: Artificial Intelligence*, *8*, 100398. [CrossRef]

Lee, J. D., & See, K. A. (2004). Trust in automation: Designing for appropriate reliance. *Human Factors*, *46*(1), 50–80. [CrossRef] [PubMed]

Li, K., Wang, P., & Chen, G. (2025). How can AI be integrated into teacher professional development programs? A systematic review based on an adapted technology-based learning model. *Teaching and Teacher Education*, *168*, 105219. [CrossRef]

Lindner, A., & Romeike, R. (2019). Teachers' Perspectives on artificial intelligence. In E. Jasutė, & S. Pozdniakov (Eds.), *ISSEP 2019—12th international conference on informatics in schools: Situation, evaluation and perspectives, local proceedings* (pp. 22–29). Springer.

Little, R. J. (1988). A test of missing completely at random for multivariate data with missing values. *Journal of the American Statistical Association*, *83*(404), 1198–1202. [CrossRef]

Little, R. J., & Rubin, D. B. (2019). *Statistical analysis with missing data* (Vol. 793). John Wiley & Sons.

Long, D., & Magerko, B. (2020, April 25–30). *What is AI literacy? Competencies and design considerations*. 2020 CHI Conference on Human Factors in Computing Systems, Honolulu, HI, USA. [CrossRef]

Lucas, M., Zhang, Y., Bem-haja, P., & Vicente, P. N. (2024). The interplay between teachers' trust in artificial intelligence and digital competence. *Education and Information Technologies*, *29*, 22991–23010. [CrossRef]

Luhmann, N. (1979). *Trust and power*. Wiley.

Ma, S., & Lei, L. (2024). The factors influencing teacher education students' willingness to adopt artificial intelligence technology for information-based teaching. *Asia Pacific Journal of Education*, *44*(1), 94–111. [CrossRef]

Martin, F., Zhuang, M., & Schaefer, D. (2024). Artificial intelligence in K–12 education: A systematic review. *Computers and Education: Artificial Intelligence*, *6*, 100195. [CrossRef]

Matthews, R. A., Pineault, L., & Hong, Y.-H. (2022). Normalizing the use of single-item measures: Validation of the single-item compendium for organizational psychology. *Journal of Business and Psychology*, *37*, 639–673. [CrossRef]

Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An integrative model of organizational trust. *Academy of Management Review*, *20*(3), 709–734. [CrossRef]

Murphy, R. F. (2019). *Artificial intelligence applications to support K-12 teachers and teaching: A review of promising applications, opportunities, and challenges*. RAND Corporation.

Nazaretsky, T., Ariely, M., Cukurova, M., & Alexandron, G. (2022). Teachers' trust in AI-powered educational technology and a professional development program to improve it. *British Journal of Educational Technology*, *53*(4), 914–931. [CrossRef]

Nuryani, A., Suciptaningsih, O. A., & Anggraini, A. E. (2026). Ethical implications of artificial intelligence implementation in elementary schools: A systematic review. *Journal of Innovation and Research in Primary Education*, *5*(1), 1135–1149. [CrossRef]

OECD. (2025). *Results from TALIS 2024: The state of teaching*. OECD Publishing. [CrossRef]

Polak, S., Schiavo, G., & Zancanaro, M. (2022). Teachers' perspective on artificial intelligence education: An initial investigation. In *CHI conference on human factors in computing systems extended abstracts* (pp. 1–7). ACM. [CrossRef]

R Core Team. (2023). *R: A language and environment for statistical computing* (Version 4.3.0). R Foundation for Statistical Computing.

Robert Bosch Stiftung. (2025). *Deutsches Schulbarometer: Befragung Lehrkräfte. Ergebnisse zur aktuellen Lage an Allgemein- und Berufsbildenden schulen*. Robert Bosch Stiftung.

Rogers, E. M. (1983). *Diffusion of innovations* (3rd ed.). Free Press.

Roll, I., & Wylie, R. (2016). Evolution and revolution in artificial intelligence in education. *International Journal of Artificial Intelligence in Education*, *26*, 582–599. [CrossRef]

Sanusi, I. T., Ayanwale, M. A., & Tolorunleke, A. E. (2024). Investigating pre-service teachers' artificial intelligence perception from the perspective of planned behavior theory. *Computers and Education: Artificial Intelligence*, *6*, 100202. [CrossRef]

Scheiter, K., Bauer, E., Omarchevska, Y., Schumacher, C., & Sailer, M. (2025). *Künstliche Intelligenz in der Schule: Eine Handreichung zum Stand in Wissenschaft und Praxis. Bundesministerium für Bildung, Familie, Senioren, Frauen und Jugend (BMFSFJ)*. Available online: https://www.empirische-bildungsforschung-bmbf.de/img/KI_Review.pdf (accessed on 21 July 2026).

Sperling, K., Stenberg, C.-J., McGrath, C., Åkerfeldt, A., Heintz, F., & Stenliden, L. (2024). In search of artificial intelligence (AI) literacy in teacher education: A scoping review. *Computers and Education Open*, *6*, 100169. [CrossRef]

Tan, X., Cheng, G., & Ling, M. H. (2025). Artificial intelligence in teaching and teacher professional development: A systematic review. *Computers and Education: Artificial Intelligence*, *8*, 100355. [CrossRef]

Tierney, N., & Cook, D. (2023). Expanding tidy data principles to facilitate missing data exploration, visualization and models of missing data. *Journal of Statistical Software*, *105*(7), 1–31. [CrossRef]

UNESCO. (2019). *Artificial intelligence in education: Challenges and opportunities for sustainable development*. UNESCO.

UNESCO. (2023). *Guidance for generative AI in education and research*. UNESCO.

UNESCO. (2024). *AI competency framework for teachers*. UNESCO. [CrossRef]

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science*, *46*(2), 186–204. [CrossRef]

Viberg, O., Cukurova, M., Feldman-Maggor, Y., Alexandron, G., Shirai, S., Kanemune, S., Wasson, B., Tømte, C., Spikol, D., Milrad, M., Coelho, R., & Kizilcec, R. F. (2025). What explains teachers' trust in AI in education across six countries? *International Journal of Artificial Intelligence in Education*, *35*(3), 1288–1316. [CrossRef]

Woo, S. E., Hofmans, J., Wille, B., & Tay, L. (2024). Person-centered modeling: Techniques for studying associations between people rather than variables. *Annual Review of Organizational Psychology and Organizational Behavior*, *11*, 453–480. [CrossRef]

Zhang, C., Hu, M., Wu, W., Kamran, F., & Wang, X. (2025). Unpacking perceived risks and AI trust influences pre-service teachers' AI acceptance: A structural equation modeling-based multi-group analysis. *Education and Information Technologies*, *30*(2), 2645–2672. [CrossRef]

Zhang, C., Schießl, J., Plößl, L., Hofmann, F., & Glaeser-Zikuda, M. (2023). Acceptance of artificial intelligence among pre-service teachers: A multigroup analysis. *International Journal of Educational Technology in Higher Education*, *20*, 49. [CrossRef]